IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BOARD OF PATENT APPEALS AND INTERFERENCES

Applicants:	Furong Zhu, Kian Soo Ong and Xiaotao Hao	Examiner:	Hines, Anne M.
Serial No.	10/583,236	Group Art Unit:	2879
Filed:	March 6, 2007	Docket No.	34018-1040
Title:	FLEXIBLE ELECTROLUMINESCENT DEVICES		
Customer No.	45263		

CERTIFICATE OF TRANSMISSION
Date of Deposit: February 4, 2010

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Jason Berry
Name: Jason Berry

APPELLANTS' APPEAL BRIEF

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Commissioner for Patents
Post Office Box 1450
Alexandria, Virginia 22313-1450

Sir:

This brief is in furtherance of the Notice of Appeal filed on November 4, 2009. Applicants hereby appeal to the Board from the decision of the Examiner in the Final Office Action mailed August 4, 2009, responsive to Applicant's Response filed on April 16, 2009, of the pending claims (1-19, 21, 23-25, 27, 28 and 30). Accordingly, claims 1-19, 21, 23-25, 27, 28 and 30 are now on Appeal.

I. REAL PARTIES IN INTEREST

The real party in interest in this appeal is the Agency for Science, Technology and Research, the assignee of record, which is a Singapore government agency.

II. RELATED APPEALS AND INTERFERENCES

Applicant is unaware of any appeals or interferences that will directly affect, or be directly affected by, or have a bearing on the Board's decision in this appeal.

III. STATUS OF CLAIMS

Claims on Appeal are claims 1-19, 21, 23-25, 27, 28 and 30, as set forth in Appendix A of this brief. Claims 1-19, 21, 23-25, 27, 28 and 30 stand finally rejected by the Examiner in the Final Office Action mailed August 4, 2009. Claims 20, 22, 26 and 29 are canceled.

IV. STATUS OF AMENDMENTS

No amendments have been filed subsequent to the final rejection of August 4, 2009, from which the present Appeal is taken.

V. SUMMARY OF CLAIMED SUBJECT MATTER

The claimed subject matter is a flexible organic light emitting device ("OLED") that provides enhanced light output, superior barrier properties, high flexibility and can be easily fabricated. The OLED comprises a flexible substrate, a lower electrode layer on the flexible substrate, an upper electrode layer and an organic region between the lower electrode layer and the upper electrode layer. *See* Specification at FIG. 1 and ¶ 14. The upper electrode layer is at least semi-transparent. *See id.* at ¶ 16. The flexible substrate comprises a metal layer and an upper substrate layer comprising a material selected from the group consisting of a plastic layer, a polymer layer and a dielectric layer. *See id* at ¶ 14. Electroluminescence can take place in the organic region when a voltage is applied between the lower electrode layer and the upper electrode layer. *See id* at ¶ 19. The metal layer and the upper substrate layer are disposed such that light generated as a result of the electroluminescence directed towards the metal layer through the upper substrate layer is reflected back to the at least semi-transparent upper electrode

layer for enhancing light output from the flexible organic light emitting device. *See id.* at FIG. 4 and ¶ 15.

VI. GROUNDS OF REJECTION TO BE REVIEWED ON APPEAL

Whether independent claim 1 and its dependent claims 9, 11, 28 and 30 are unpatentable under 35 U.S.C. § 103(a) over U.S. Publication No. US 2002/0173354 to Winans ("Winans") in view of U.S. Patent No. 6,856,086 to Grace et al. ("Grace").

Whether independent claim 1 and its dependent claims 2-8, 12-13, 15 and 23-24 are unpatentable under 35 U.S.C. § 103(a) over U.S. Publication No. US 2003/0178937 to Mishima ("Mishima") in view of Grace.

Specifically, the issues on appeal are (1) whether each and every limitation of the claims is taught by the references; and (2) as to Grace, whether the references could be combined by one having ordinary skill in the art, in particular whether liquid crystal display ("LCD") technology can be applied to the present claims relating to the distinct flexible organic light emitting device ("OLED") technology.

VII. ARGUMENT

A. Background

Independent claim 1 and many of its dependent claims stand rejected under § 103(a) over U.S. Patent Application Publication No. US 2002/0173354 to Winans ("Winans") in view of U.S. Patent No. 6,856,086 to Grace et al. ("Grace") and U.S. Patent Application Publication No. US 2003/0178937 to Mishima ("Mishima") in view of Grace. Where references are inapplicable to support an obviousness rejection for an independent claim, the references also are inapplicable to the dependent claims because the claim limitations undisclosed by the references are also part of the dependent claims.

The devices of the present application include flexible OLEDs that provide enhanced light output, superior barrier properties, high flexibility and can be easily fabricated. The OLED comprises a metal layer and an upper substrate layer disposed such that *light generated as a result of the electroluminescence* directed towards the metal layer through the upper substrate

layer *is reflected back to the at least semi-transparent upper electrode layer for enhancing light output* from the flexible organic light emitting device.

None of the cited references teaches or suggests using a metal layer to reflect light resulting from electroluminescence and enhance light output. Rather, to the extent the references disclose a metal layer, the metal layer is used to prevent entry of light through the back of the lighting device. The disclosure of Winans teaches light-emitting interface displays for input and output of gaming information on a gaming machine including OLEDs that emit light through the top cathode layer and wherein the substrate may be a flexible material such as plastic film or reflective metal foil to make the device more impact resistant. The disclosure of Grace teaches a display device including OLEDs having a front panel and a back panel wherein one of the panels includes a rigid substrate and the other panel includes a flexible substrate wherein the back panel has an opaque coating to prevent ambient light from entering the device through the back panel. The disclosure of Mishima teaches a light-emitting device comprising an anode, one or more organic compound layers and a transparent cathode wherein a flexible support substrate is made of a metal foil having an insulating layer.

In the most recent rejection, from which this appeal is taken, the Examiner relied on combinations of Winans, Mishima and Grace to satisfy the limitations of independent claim 1.

B. Rejection of claims 1, 9, 11, 28 and 30 under 103(a) over Winans in view of Grace

1. THE CITED REFERENCES DO NOT TEACH OR SUGGEST THE LIMITATION OF THE METAL LAYER AND UPPER SUBSTRATE LAYER DISPOSED SUCH THAT LIGHT RESULTING FROM ELECTROLUMINESCENCE IS REFLECTED BACK FOR ENHANCING LIGHT OUTPUT, AS RECITED IN INDEPENDENT CLAIM 1

The failure of an asserted combination to teach or suggest each and every feature of a claim is fatal to an obviousness rejection under 35 U.S.C. § 103. An asserted combination of references must teach or suggest each and every claim feature. *See In re Royka*, 490 F.2d 981 (C.C.P.A. 1974). The Board recently stated:

> When determining whether a claim is obvious, an examiner must make "a searching comparison of the claimed invention – *including all its limitations* – with the teaching of the prior art." Thus, "obviousness requires a suggestion of all limitations in a claim." Moreover, as the Supreme Court recently stated, "*there must be some articulated reasoning* with some rational underpinning to support the legal conclusion of obviousness." *In re Wada and Murphy*, Appeal 2007-3733, 7 (B.P.A.I. 2007) (*citing CFMT, Inc. v. Yieldup Intern. Corp.*, 349 F.3d 1333, 1342 (Fed. Cir. 2003)) (*citing In re Ochiai*, 71 F.3d 1565, 1572 (Fed. Cir. 1995)) (*citing KSR v. Teleflex*, 127 S. Ct. 1727 at 1741 (2007)).

The necessary presence of all claim features is axiomatic, since the Supreme Court has long held that obviousness is a question of law based on underlying factual inquiries, including … ascertaining the differences between the claimed invention and the prior art. *Graham v. John Deere Co.*, 383 U.S. 1 (1966). In sum, it remains well-settled law that obviousness requires at least a suggestion of all of the features in a claim.

Here, the cited references cannot render independent claim 1 obvious because they fail to teach or suggest all of the features of claim 1. Independent claim 1 recites a flexible organic light emitting device comprising a flexible substrate comprising a metal layer and an upper substrate layer comprising a material selected from the group consisting of a plastic layer, a polymer layer and a dielectric layer, wherein the lower electrode is formed on the upper substrate layer. The metal layer and upper substrate layer are disposed such that *light generated as a result of electroluminescence* directed towards the metal layer through the upper substrate layer *is reflected back to the at least semi-transparent upper electrode layer for enhancing light output* from the flexible organic light emitting device.

The Winans reference does not teach or suggest reflecting light generated as a result of the electrode luminescence for enhancing light output from the flexible organic light emitting device. Although Winans teaches that the substrate "may be a flexible material such as an optically-clear plastic film or a reflective metal foil" (*See* Winans at ¶ 0119), there is no teaching or suggestion of any involvement or use of the reflective metal foil in reflecting light resulting from electroluminescence for enhancing light output from the light emitting device. Rather, in the Winans device the flexible material, which may be a reflective metal foil, is used to make the OLED display more impact resistant. *See* Winans at ¶0119. Winans also suggests that the reflective metal foil could be used to prevent ambient light from entering the device through the

substrate or back panel. *See* Winans at ¶ 0120 ("when the OLED cell structure is transparent and emits light through the top cathode layer 454 then it may be used on top of opaque substrates such as metal, foils and wood that may form the exterior surface of a gaming machine"). Thus, the disclosure of Winans fails to teach or suggest a light emitting device that uses a reflective metal foil to reflect light resulting from electroluminescence to enhance light output and fails to teach one of skill in the art how a reflective metal foil could be so used.

Grace does nothing to cure the infirmities of Winans. Grace makes no reference to using reflective metal coatings to enhance light output. Rather, Grace teaches that a light emitting device may be configured to inhibit ambient light from entering the device through the back panel to improve the contrast ratio of the display device. *See* Grace at col. 19, lines 55-64. Grace does not disclose, teach or suggest "said metal layer and said upper substrate layer are disposed such that light generated as a result of said electroluminescence directed towards said metal layer through said upper substrate layer is reflected back to said at least semi-transparent upper electrode layer for enhancing light output from the flexible organic light emitting device" as recited in independent claim 1.

Because the references do not teach or suggest a metal layer and upper substrate layer are disposed such that *light generated as a result of electroluminescence* directed towards the metal layer through the upper substrate layer *is reflected back* to the at least semi-transparent upper electrode layer *for enhancing light output* from the flexible organic light emitting device, independent claim 1 and its dependent claims 9, 11, 28 and 30 are not obvious over the references cited. Withdrawal of the rejection is kindly requested.

C. Rejection of claims 1, 2-8, 12-13, 15 and 23-24 under 103(a) over Mishima in view of Grace

THE CITED REFERENCES DO NOT TEACH OR SUGGEST THE LIMITATION OF THE METAL LAYER AND UPPER SUBSTRATE LAYER DISPOSED SUCH THAT LIGHT RESULTING FROM ELECTROLUMINESCENCE IS REFLECTED BACK FOR ENHANCING LIGHT OUTPUT, AS RECITED IN INDEPENDENT CLAIM 1

Claim 1 recites a flexible organic light emitting device comprising a flexible substrate comprising a metal layer and an upper substrate layer comprising a material selected from the group consisting of a plastic layer, a polymer layer and a dielectric layer, wherein the lower electrode is formed on the upper substrate layer. The metal layer and upper substrate layer are disposed such that *light generated as a result of electroluminescence* directed towards the metal layer through the upper substrate layer *is reflected back* to the at least semi-transparent upper electrode layer *for enhancing light output* from the flexible organic light emitting device.

The most recent Office Action acknowledges that Mishima fails to teach that the metal foil is reflective such that light generated as a result of electroluminescence directed towards the metal foil is reflected back to the at least semi-transparent upper electrode for enhancing light output from the flexible organic light emitting device (August 4, 2009 Office Action at 4). Grace does not make up for the deficiencies of Mishima. As discussed in detail above, Grace does not teach or suggest reflective metal coatings used to enhance light output.

Because the references do not teach or suggest a metal layer and upper substrate layer disposed such that light generated as a result of electroluminescence directed towards the metal layer through the upper substrate layer is reflected back to the at least semi-transparent upper electrode layer *for enhancing light output* from the flexible organic light emitting device, independent claim 1 and its dependent claims 2-8, 12-13, 15 and 23-24 are not obvious over the references cited. Withdrawal of the rejection is kindly requested.

Further, in relation to claims 2 and 3, claim 2 recites a flexible organic light emitting device of claim 1, wherein at least one of said upper and lower electrodes has an interfacial modified surface for enhancing charge carrier injection. In the most recent Office Action the

examiner supports his rejection with reference to paragraph [0033] of Mishima. However, paragraph [0033] of Mishima merely discloses selection of a material for the anode, for achieving a desired work function of > 4eV. The various materials, mixtures or laminates described have to satisfy the work function requirement disclosed. Significantly, this is disclosure simply of a material choice to satisfy the requirement. Nowhere is there any disclosure of *an interfacial modified surface* of the anode in Mishima, as defined in claim 2. Therefore, because the references do not teach or suggest *at least one of said upper and lower electrodes has an interfacial modified surface for enhancing charge carrier injection*, dependent claim 2, and dependent claim 3 which is dependent on claim 2 as an intervening claim, are not obvious over the references cited.

D. Rejection of claims 1-9, 11-13, 15, 23-24, 28 and 30 under 103(a) in view of Grace as a secondary reference

GRACE IS NOT A PROPER REFERENCE BECAUSE IT RELATES TO AN ENTIRELY DIFFERENT TECHNOLOGY

The sections of Grace cited in the most recent Office Action are not applicable to the present claims because those sections pertain to an entirely different technology. The Office Action cited FIG. 1, column 4, lines 15-23 and column 7, lines 3-11, which describe LCD devices, (i.e. gray scale shutters for light), not OLEDs, which are primary light emitting devices, i.e. primary light sources. In particular, the Office Action focuses on column 7, lines 3-11 of Grace for a teaching of a metal layer functioning as a reflective layer. *See* August 4, 2009 Office Action at 12. However, the disclosure in column 7, lines 3-11 constitutes nothing more than reference to an existing form of LCD devices, namely reflective LCD devices.

Reflective LCD devices operate differently from OLEDs. In reflective LCDs, a mirror is placed behind the LCD layer to reflect ambient light or light from an external source. The light enters the LCD layer, reflects off the mirror and travels back through the LCD layer. OLEDs, by contrast, are self-luminescent so they do not require light from an external source. A typical OLED comprises an organic light-emitting material disposed between a cathode layer that can inject electrons and an anode layer that can inject holes.

Accordingly, the sections of Grace cited in the most recent Office Action are not applicable to the present claims and withdrawal of the rejections based upon Grace are kindly requested

E. Conclusion

Winans, Mishima and Grace cannot be used to support a rejection of claims 1-9, 11-13, 15, 23-24, 28 and 30 under 35 U.S.C. § 103(a) because the cited references do not teach or suggest the limitation of a metal layer and upper substrate layer disposed such that light generated as a result of electroluminescence directed towards the metal layer through the upper substrate layer is reflected back to the at least semi-transparent upper electrode layer *for enhancing light output* from the flexible organic light emitting device. Moreover, the sections of Grace cited in the most recent Office Action are not applicable to the present claims because they pertain to entirely different technology, namely LCDs, not OLED technology as presently claimed.

VIII. CLAIMS APPENDIX

A complete listing of the claims involved in this appeal are attached to this Appeal Brief as Appendix A.

IX. EVIDENCE APPENDIX

Applicants submit the following evidence:

U.S. Patent Application Publication No. 2002/0173354 (Winans) as Appendix B;

U.S. Patent No. 6,856,086 (Grace) as Appendix C; and

U.S. Patent Application Publication No. 2003/0178937 (Mishima) as Appendix D.

X. RELATED PROCEEDINGS APPENDIX

Applicant states that there are no relevant related proceedings and therefore no Related Proceeding Appendix is hereby attached.

XI. CONCLUSION

It is respectfully requested that the panel return a decision concurring with Appellants' position that no *prima facie* case of obviousness has been set forth. Reliance on Winans, Grace and Mishima cannot be used to support a rejection under 35 U.S.C. § 103(a) because the cited references do not teach the limitation of a metal layer and upper substrate layer disposed such that light generated as a result of electroluminescence directed towards the metal layer through the upper substrate layer is *reflected back to the at least semi-transparent upper electrode layer for enhancing light output* from the flexible organic light emitting device. Moreover, the sections of Grace cited in the most recent Office Action are not applicable to the present claims because they pertain to entirely different technology, namely LCDs, not OLED technology as presently claimed.

The rejections should be withdrawn, in light of the arguments, points, and authorities presented in this Appeal Brief.

XII. ORAL HEARING

An Oral Hearing is requested.

Respectfully submitted,

Date: February 4, 2010

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Attachments:
- Appendix A: Claims on Appeal
- Appendix B: Evidence
- Appendix C: Evidence
- Appendix D: Evidence

Appendix A

1. (Previously Presented) A flexible organic light emitting device comprising:

a flexible substrate,

a lower electrode layer on said flexible substrate,

an upper electrode layer that is at least semi-transparent,

an organic region between said lower electrode layer and said upper electrode layer, in which electroluminescence can take place when a voltage is applied between said lower electrode layer and said upper electrode layer,

wherein said flexible substrate comprises a metal layer and an upper substrate layer comprising a material selected from the group consisting of a plastic layer, a polymer layer and a dielectric layer, wherein the lower electrode is formed on the upper substrate layer; and

further wherein said metal layer and said upper substrate layer are disposed such that light generated as a result of said electroluminescence directed towards said metal layer through said upper substrate layer is reflected back to said at least semi-transparent upper electrode layer for enhancing light output from the flexible organic light emitting device.

2. (Previously Presented) The flexible organic light emitting device of claim 1, wherein at least one of said upper and lower electrodes has an interfacial modified surface for enhancing charge carrier injection.

3. (Previously Presented) The flexible organic light emitting device of claim 2, wherein said interfacial modified surface is formed by modifying said at least one of the upper or lower electrodes comprises a metal electrode, and said metal electrode is modified using inorganic or organic materials or a TCO.

4. (Previously Presented) The flexible organic light emitting device of claim 1, wherein said metal layer is comprised of an aluminum layer, and the upper surface layer is comprised of a plastic layer, wherein the plastic layer is laminated to or coated with the

aluminum layer, and the plastic layer is positioned between the lower electrode layer and the aluminum layer.

5. (Previously Presented) The flexible organic light emitting device of claim 1, wherein said metal layer is comprised of a steel foil.

6. (Previously Presented) The flexible organic light emitting device of claim 1 wherein said upper substrate layer further functions as an electrical isolation layer between said metal layer and said lower electrode layer.

7. (Previously Presented) The flexible organic light emitting device of claim 6, wherein said upper substrate layer is a spin-coated polymeric layer or a dielectric layer.

8. (Previously Presented) The flexible organic light emitting device of claim 5, wherein the upper substrate layer further functions as an isolation layer between said steel foil and said lower electrode layer.

9. (Original) The flexible organic light emitting device of claim 1, wherein said upper electrode layer is transparent.

10. (Original) The flexible organic light emitting device of claim 1, wherein said upper electrode layer is a semitransparent or transparent anode.

11. (Original) The flexible organic light emitting device of claim 1, wherein said upper electrode layer is a semitransparent or transparent cathode.

12. (Original) The flexible organic light emitting device of claim 1, wherein said upper electrode layer is a multilayer structure comprising at least one semitransparent or transparent conductive film.

13. (Previously Presented) The flexible organic light emitting device of claim 12, wherein said multilayer structure comprises an index-matching layer of a material having a refractive index chosen such that said light output is further enhanced, and a charge carrier injection layer.

14. (Previously Presented) The flexible organic light emitting device of claim 13, wherein said index-matching layer comprises an organic material having a refractive index effective for enhancing light output.

15. (Previously Presented) The flexible organic light emitting device of claim 13, wherein said index-matching layer comprises an inorganic material having a refractive index effective for enhancing light output.

16. (Previously Presented) The flexible organic light emitting device of claim 13, wherein said multilayer structure is an anode and said charge carrier injection layer is a hole injection layer.

17. (Previously Presented) The flexible organic light emitting device of claim 16, wherein said hole injection layer comprises a high work function metal or a transparent conductive oxide (TCO).

18. (Previously Presented) The flexible organic light emitting device of claim 17, wherein said high work function metal is gold or silver.

19. (Previously Presented) The flexible organic light emitting device of claim 17, wherein said TCO is metal oxide selected from the group consisting of indium-tin-oxide (ITO), zinc-indium-oxide, aluminum-doped zinc oxide, Ga-In-Sn-O, SnO_2, Zn-In-Sn-O, and Ga-In-O.

20. (Canceled)

21. (Previously Presented) The flexible organic light emitting device of claim 16, wherein said hole injection layer comprises an organic material effective for hole injection or an inorganic material effective for hole injection, or a combination of inorganic and organic materials that are effective for hole injection.

22. (Canceled)

23. (Previously Presented) The flexible organic light emitting device of claim 13, wherein said multilayer structure is a cathode and said charge carrier injection layer is an electron injection layer.

24. (Previously Presented) The flexible organic light emitting device of claim 23, wherein said electron injection layer comprises a low work function metal.

25. (Previously Presented) The flexible organic light emitting device of claim 24, wherein said low work function metal is a rare earth metal and said index-matching layer comprises tris-(8-hydroxyquinoline) aluminum (Alq3) or N,N'-di(naphthalene-1-yl)-N,N'-diphenylbenzidine (NPB).

26. (Canceled)

27. (Previously Presented) The flexible organic light emitting device of claim 23, wherein said cathode comprises a silver layer and said electron injection layer is comprised of a calcium sub-layer over a lithium fluoride sub-layer, the silver layer being formed over the calcium layer.

28. (Previously Presented) The flexible organic light emitting device of claim 1, wherein said organic region comprises a hole transporting layer and an emissive layer and/or an electron transporting layer.

29. (Canceled)

30. (Previously Presented) The flexible organic light emitting device of claim 1, wherein said organic region comprises (i) a hole transporting layer, (ii) an emissive layer, and (iii) an electron transporting layer.

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APPENDIX B

US 20020173354A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2002/0173354 A1
Winans et al. (43) Pub. Date: Nov. 21, 2002

(54) LIGHT EMITTING INTERFACE DISPLAYS FOR A GAMING MACHINE

(75) Inventors: Ron Winans, Sparks, NV (US); Richard Ollins, Las Vegas, NV (US)

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(73) Assignee: IGT

(21) Appl. No.: 10/139,801

(22) Filed: May 3, 2002

Related U.S. Application Data

(60) Provisional application No. 60/288,603, filed on May 4, 2001.

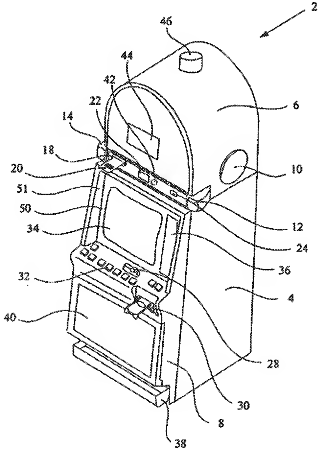
Publication Classification

(51) Int. Cl.[7] A63F 13/00

(52) U.S. Cl. 463/20

(57) ABSTRACT

A disclosed thin light-emitting interface displays may be mounted to a surface on the gaming machine. The light-emitting elements used in the interface displays may be provided from electro-luminescent elements, organic light emitting diode (OLED) elements and combinations thereof. The thin light-emitting interface displays may be used to input and output gaming information on the gaming machine. The gaming information that is input and output via the interface display may be used to provide: 1) a game of chance played on the gaming machine, 2) player tracking services, 3) game services available on the gaming machine and 4) attract features. In one embodiment, a game input interface display is provided with a plurality of input buttons where a number and a format of the input buttons are dynamically configurable for different types of games of chance played on the gaming machine



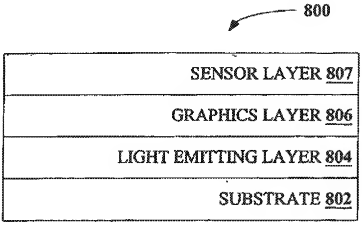


FIGURE 1A

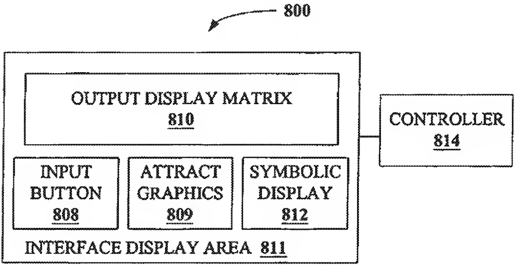


FIGURE 1B

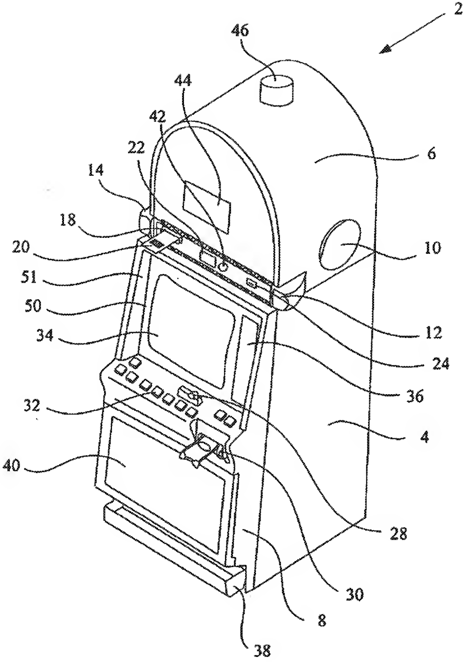


FIGURE 2

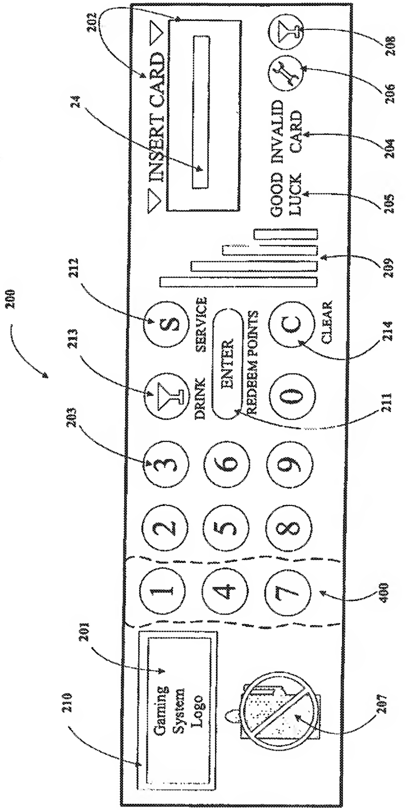

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FIGURE 3A

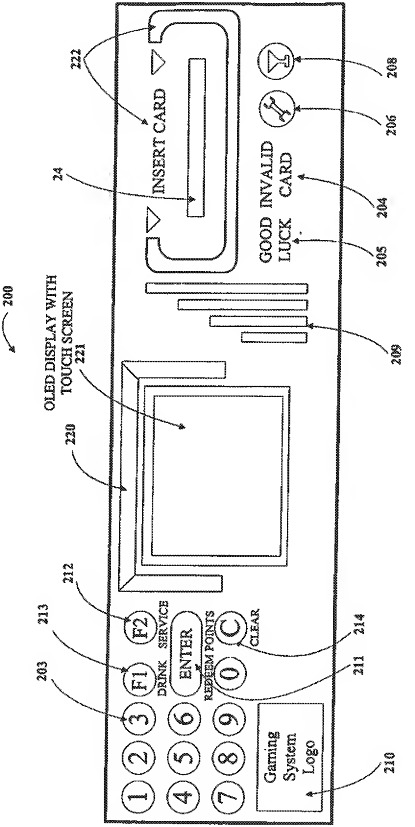
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FIGURE 3B

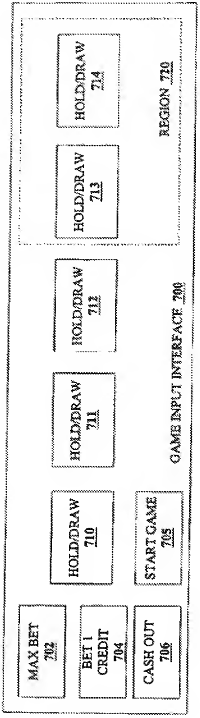

FIGURE 4A

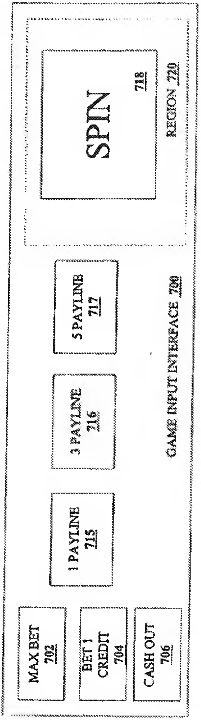

FIGURE 4B

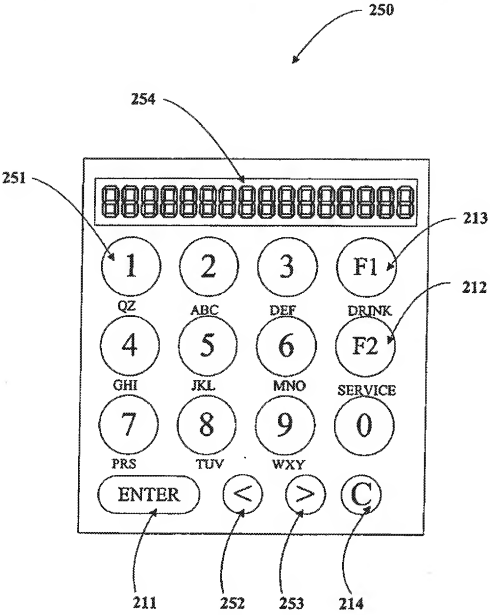

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FIGURE 5

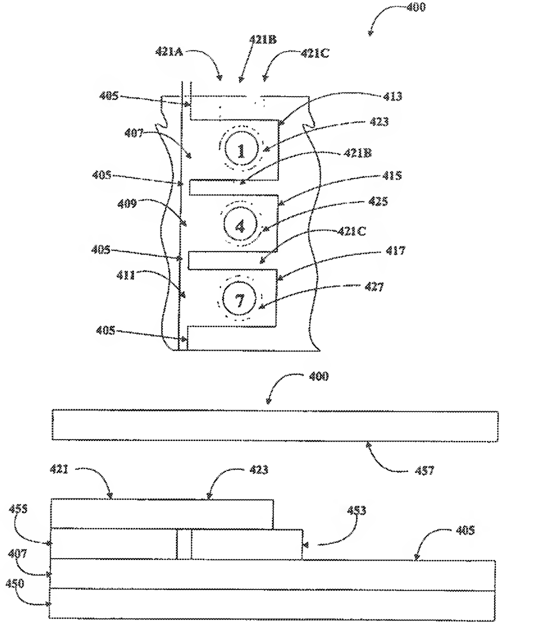
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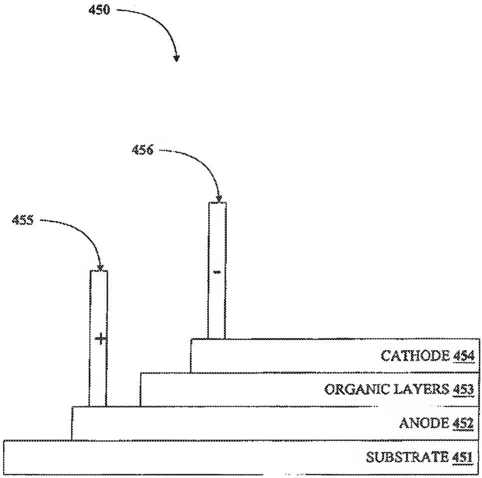
FIGURE 6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ANODE 452
SUBSTRATE 451

FIGURE 7

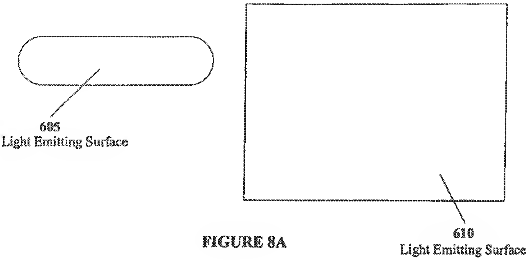


FIGURE 8A

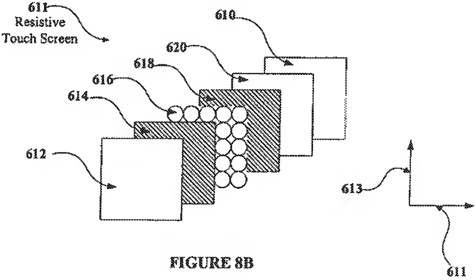


FIGURE 8B

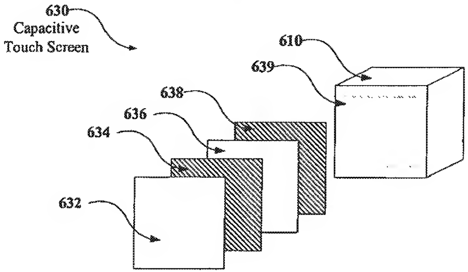


FIGURE 8C

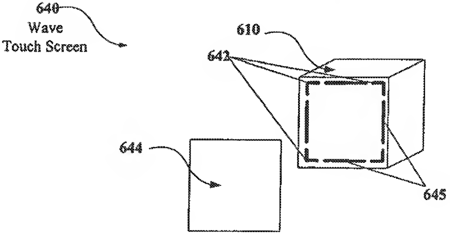


FIGURE 8D

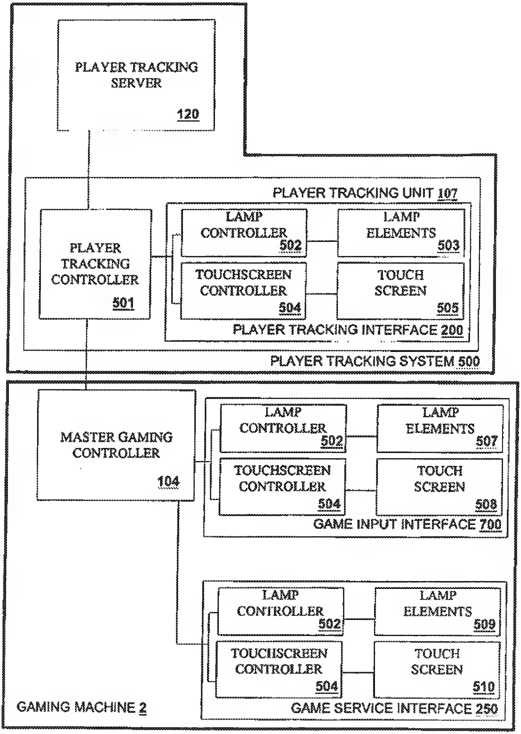
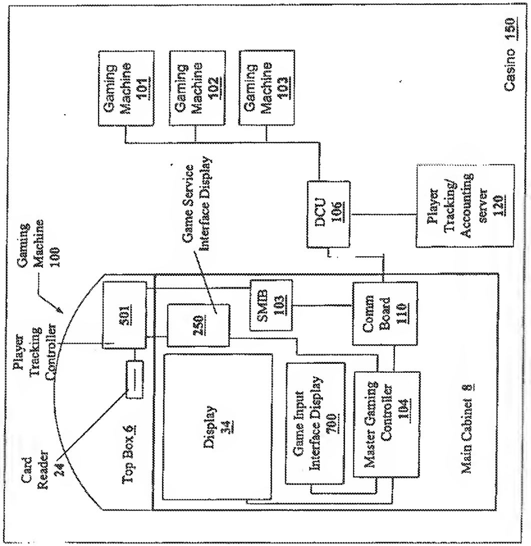

PLAYER TRACKING SERVER
120
PLAYER TRACKING UNIT 107
PLAYER TRACKING CONTROLLER
501
LAMP CONTROLLER
502
LAMP ELEMENTS
503
TOUCHSCREEN CONTROLLER
504
TOUCH SCREEN
505
PLAYER TRACKING INTERFACE 200
PLAYER TRACKING SYSTEM 500
MASTER GAMING CONTROLLER
104
LAMP CONTROLLER
502
LAMP ELEMENTS
507
TOUCHSCREEN CONTROLLER
504
TOUCH SCREEN
508
GAME INPUT INTERFACE 700
LAMP CONTROLLER
502
LAMP ELEMENTS
509
TOUCHSCREEN CONTROLLER
504
TOUCH SCREEN
510
GAMING MACHINE 2
GAME SERVICE INTERFACE 250

FIGURE 9

FIGURE 10



Casino 150
Gaming Machine 101
Gaming Machine 102
Gaming Machine 103
Game Service Interface Display
DCU 106
Player Tracking/ Accounting server 120
Gaming Machine 100
Player Tracking Controller
Card Reader 24
Top Box 6
501
250
SMIB 103
Comm Board 110
Display 34
Game Input Interface Display 700
Master Gaming Controller 104
Main Cabinet 8

LIGHT EMITTING INTERFACE DISPLAYS FOR A GAMING MACHINE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119(e) from co-pending U.S. Provisional Patent Application No. 60/288,603, filed May 4, 2001, naming Winans et al. as inventors, and titled "PLAYER TRACKING PANEL."

BACKGROUND OF THE INVENTION

[0002] This invention relates to interfaces for gaming machines such as video slot machines and video poker machines. More particularly, the present invention relates to light-emitting interface displays using electro-luminescent elements and/or organic light emitting diode elements for providing player tracking interfaces and game playing interfaces.

[0003] There are a wide variety of associated devices that can be connected to a gaming machine such as a slot machine or video poker machine. Some examples of these devices are player tracking units, lights, ticket printers, card readers, speakers, bill validators, ticket readers, coin acceptors, display panels, key pads, coin hoppers and button pads. Many of these devices are built into the gaming machine or components associated with the gaming machine such as a top box which usually sits on top of the gaming machine.

[0004] Typically, utilizing a master gaming controller, the gaming machine controls various combinations of devices that allow a player to play a game on the gaming machine and also encourage game play on the gaming machine. For example, a game played on a gaming machine usually requires a player to input money or indicia of credit into the gaming machine, indicate a wager amount, and initiate a game play. These steps require the gaming machine to control input devices, including bill validators and coin acceptors, to accept money into the gaming machine and recognize user inputs from devices, such as button pads and levers, to determine the wager amount and initiate game play.

[0005] After game play has been initiated, the gaming machine determines a game outcome, presents the game outcome to the player and may dispense an award of some type depending on the outcome of the game. A game outcome presentation may utilize many different visual and audio components such as flashing lights, music, sounds and graphics. The visual and audio components of the game outcome presentation may be used to draw a players attention to various game features and to heighten the players interest in additional game play. Maintaining a game player's interest in game play, such as on a gaming machine or during other gaming activities, is an important consideration for an operator of a gaming establishment.

[0006] One related method of gaining and maintaining a game player's interest in game play may be to provide a gaming machine with a plurality of games. Traditionally, gaming machines have provided only a single game. When the game player has been playing a game on a first gaming machine and desires to play a different type of game, the player must physically leave the first gaming machine and locate a second gaming machine at the gaming location, such as a casino, that offers the different type of game in which they are interested in playing. When the player is allowed to select games for game play at the same gaming machine, the game player may participate in game play for a longer time. Therefore, it is desired within the gaming industry to provide gaming machines with the capability to offer multiple games that may be selected by the player.

[0007] One difficulty with providing a gaming machine with different games is that different games may require different inputs. For instance, a multi-payline slot game may require different inputs than a single payline slot game. As another example, a video black jack game may require different inputs than a slot game or a video poker game. Therefore, a design for an input interface may be complicated by different inputs required for different games. In view of the above, it would be desirable to provide apparatus and methods for a gaming machine input interface that may be used with many types of games.

[0008] Another related method of gaining and maintaining a game player's interest in game play are player tracking programs which are offered at various casinos. Player tracking programs provide rewards to players that typically correspond to the player's level of patronage (e.g., to the player's playing frequency and/or total amount of game plays at a given casino). Player tracking rewards may be free meals, free lodging and/or free entertainment. These rewards may help to sustain a game player's interest in additional game play during a visit to a gaming establishment and may entice a player to visit a gaming establishment to partake in various gaming activities.

[0009] Player tracking cards and player tracking programs are becoming more and more popular. They have become a de facto marketing method of doing business at casinos. The programs allow a casino to identify and reward customers based upon their previous game play history. In particular, a goal of the casinos is to identify and then to provide a higher level of service to certain groups of players identified as especially valuable to the casinos. An incentive of a casino for providing these services is to generate "brand" loyalty, and thus, repeat business from its valued customers. For instance, players that visit the casino, on average, once a week may be deemed as "special" customers and the casino may desire to cultivate a "special" relationship with these customers. In general, the selection of gaming services offered to players via loyalty programs, such as player tracking programs, is increasing. Also, the gaming services offered to a particular player are becoming more focused based upon the desires of a particular player.

[0010] A disadvantage of current player tracking units is that the player interface is not necessarily suited for providing increasingly complex and diverse gaming services to game players that are customized to an individual player's preferences. Further, it is not easy to modify current player tracking interfaces to enable them to provide new game services. In view of the above, it would be desirable to provide apparatus and methods for a player tracking unit interface that allows it to be configured for a diverse range of gaming services and is upgraded easily.

SUMMARY OF THE INVENTION

[0011] This invention addresses the needs indicated above by providing thin light-emitting interface displays that may

be mounted to a surface on the gaming machine. The light-emitting elements used in the interface displays may be provided from electro-luminescent elements, organic light emitting diode (OLED) elements and combinations thereof. The thin light-emitting interface displays may be used to input and output gaming information on the gaming machine. The gaming information that is input and output via the interface display may be used to provide: 1) a game of chance played on the gaming machine, 2) player tracking services, 3) game services available on the gaming machine and 4) attract features. In one embodiment, a game input interface display is provided with a plurality of input buttons where a number and a format of the input buttons are dynamically configurable for different types of games of chance played on the gaming machine.

[0012] A first aspect of the present invention provides an interface display for inputting and outputting gaming information on a gaming machine. The interface display may be generally characterized as comprising: 1) a substrate, 2) a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information; 3) a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements; 4) a plurality of sensors for detecting selections of the input areas; and 5) one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors. The plurality of sensors may be formed in a sensor layer and may be activated by at least one of contact with an object and a proximity of an object, such as a finger or a stylus. The sensor layer is at least one of a capacitive touch screen, a resistive touch screen, a wave touch screen and combinations thereof.

[0013] The interface display may be mounted to an exterior surface of the gaming machine such as an exterior face of a player tracking unit on the gaming machine. Further, the interface display may be integrated into an exterior surface of the gaming machine. Using the electro-luminescent elements in the interface display, gaming information may be conveyed using one or more of a light intensity, a color pattern, a light pattern and a flash rate. The light intensity of each electro-luminescent element may be controlled by an amount of current supplied to each electro-luminescent element.

[0014] In particular embodiments, the thickness of the interface display may be less than about 3 mm and the thickness of the light emitting layer may be less than about 1 micron. The substrate may be formed from a flexible material such as a plastic film or a metal foil. The substrate may also be glass.

[0015] In other embodiments, the one or more of the electro-luminescent elements may be formed in a shape of a pattern, such as a symbol, an icon, a logo, an alpha-numeric text symbol and a word. The plurality of electro-luminescent elements may be arranged in a plurality of stacked layers where the electro-luminescent elements in each of the stacked layers are arranged in different patterns. In one embodiment, a first pattern may be displayed by activating the electro-luminescent elements in a first layer of the stacked layers and then a second pattern may be displayed by activating the electro-luminescent elements in a second layer of the stacked layers.

[0016] A portion of the electro-luminescent elements may be a matrix of organic light emitting diodes (OLEDs) where each OLED forms a pixel in the matrix. The OLED pixels in the matrix may be controlled in an active matrix, a passive matrix and combinations thereof. Groups of OLED pixels may be controlled to display symbols, icons, logo, alpha-numeric text and video frame data.

[0017] A plurality of patterns may be formed in a graphics layer where the plurality of patterns are illuminated by one or more of the electro-luminescent elements. A portion of the patterns may be used to display gaming information. A shape of the patterns may be selected from the group consisting of a symbol, an icon, a logo, a word and an alpha-numeric text symbol. Further, the one or more of the patterns is located in the input areas.

[0018] The interface display may be operable to vary a number of input areas, a shape of an input area, a size of an input area, a color of an input area and combinations thereof. A matrix of electro-luminescent elements may be located in one or more of the input areas. The matrix of electro-luminescent elements may be used to generate a plurality of patterns in the one or more input areas. In one embodiment, a first pattern generated by the matrix of electro-luminescent elements in a first input area may be used to display a first type of gaming information and a second pattern generated by the matrix of electro-luminescent elements in the first input area may be used to display a second type of gaming information. In another embodiment, a first pattern generated by the matrix of electro-luminescent elements in a first input area may be used to display a first type of gaming information in a first language and a second pattern generated by the matrix of electro-luminescent elements in the first input area may be used to display the first type of gaming information in a second language.

[0019] The one or more of the input areas may be used for inputting player tracking information. In another embodiment, a portion of the input areas may be used for inputting gaming information for playing a game of chance on the gaming machine. The portion of the input areas for inputting gaming information for playing the game of chance may be dynamically configurable to display different input selections used by different types of games of chance played on the gaming machine. In yet another embodiment, a portion of the input areas are used to input gaming information may be used for providing a game service on the gaming machine. The game service is selected from the group consisting of i) viewing account information, ii) performing account transactions iii) receiving operating instructions for the gaming machine, iv) redeeming prizes or comps, v) making entertainment service reservations, vi) participating in casino promotions, vii) selecting entertainment choices for output via video and audio output mechanisms on the gaming machine, viii) playing games and bonus games, ix) performing numerical calculations, x) accessing diagnostic menus, xi) displaying player tracking unit status information, xii) displaying gaming machine status information, xiii) accessing gaming machine metering information and xiv) displaying player status information.

[0020] Another aspect of the present invention provides a gaming machine. The gaming machine may be generally characterized as comprising: 1) a gaming machine cabinet;

2) a master gaming controller for controlling one or more games of chance played on the gaming machine located within the interior of the gaming machine; 3) a main display for displaying the game of chance; and 4) an interface display for inputting and outputting gaming information mounted to an exterior surface of the gaming machine cabinet, in communication with the master gaming controller and separate from the main display. The interface display may be generally characterized as comprising: a) a substrate; b) a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information; c) a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements; d) a plurality of sensors for detecting selections of the input areas; and e) one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors. The plurality of sensors may be formed in a sensor layer and are activated by at least one of contact with an object and a proximity of an object, such as finger or a stylus. The sensor layer is at least one of a capacitive touch screen, a resistive touch screen, a wave touch screen and combinations thereof.

[0021] The one or more games of chance may be selected from the group consisting of video slot games, mechanical slot games, video black jack games, video poker games, video keno games, video pachinko games, video card games, video games of chance and combinations thereof. A portion of the input areas are may be used for inputting gaming information for playing a game of chance on the gaming machine. Further, the portion of the input areas for inputting gaming information for playing the game of chance may be dynamically configurable to display different input selections used by different types of games of chance played on the gaming machine.

[0022] Yet another aspect of the present invention provides a gaming machine. The gaming machine may be generally characterized as comprising: 1) a gaming machine cabinet; 2) a master gaming controller for controlling one or more games of chance played on the gaming machine located within the interior of the gaming machine; 3) a main display for displaying the game of chance; 4) a player tracking unit mounted to the gaming machine cabinet and in communication with the master gaming controller and a player tracking server. The player tracking unit may be generally characterized as comprising: a) a player tracking controller; b) one or more player tracking devices; and c) an interface display for inputting and outputting player tracking information mounted to an exterior surface of the gaming machine cabinet, in communication with the player tracking controller and separate from the main display where the interface display comprises; i) a substrate; ii) a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information; iii) a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements; iv) a plurality of sensors for detecting selections of the input areas; and v) one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors. The interface display may be mounted to an exterior surface of the player tracking unit. Further, the interface display may communicate with the master gaming controller and may be operable to allow control by the master gaming controller.

[0023] Another aspect of the invention pertains to computer program products including a machine-readable medium on which is stored program instructions for implementing any of the methods described above. Any of the methods of this invention may be represented as program instructions and/or data structures, databases, etc. that can be provided on such computer readable media such as smart card, compact flash memory card, memory stick, RAM, CD-ROM, CD-DVD, hard drive, etc.

[0024] These and other features and advantages of the invention will be spelled out in more detail below with reference to the associated drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIGS. 1A-1B are block diagrams of thin interface displays for embodiments of the present invention.

[0026] FIG. 2 is a perspective drawing of a video gaming machine of the present invention.

[0027] FIGS. 3A and 3B are block diagrams of a player tracking interface display (PTID) 200.

[0028] FIGS. 4A and 4B are block diagrams of a game input interface display (GIID) 700.

[0029] FIG. 5 is a block diagram of a game service interface display (GSID) 250 of the present invention.

[0030] FIGS. 6A and 6B depicts an electro-luminescent portion 400 of the player tracking interface display 200 shown in FIG. 3A in greater detail.

[0031] FIG. 7 is a block diagram of an Organic Light Emitting Diode (OLED) that may be used with the present invention.

[0032] FIGS. 8A-8D are block diagrams of sensor layers mounted to light emitting layers for some embodiments of the present invention.

[0033] FIG. 9 is a block diagram of a player tracking system and a gaming machine with interface displays of the present invention.

[0034] FIG. 10 is a block diagram of a number of gaming machines with player tracking units connected to a player tracking server.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0035] In the present invention, thin light-emitting interface displays that may be mounted to a surface on the gaming machine are described. The light-emitting elements used in the interface displays may be provided from a plurality of electro-luminescent elements. An electro-luminescent element may be formed in a pattern, such as a symbol or may be formed as a pixel in matrix of electro-luminescent elements. An organic light emitting diode (OLED) elements is one example of an electro-luminescent element that may be used with the present invention.

[0036] The thin light-emitting interface displays may be used to input and output gaming information on the gaming machine. The gaming information that is input and output via the interface display may be used to provide: 1) a game of chance played on the gaming machine, 2) player tracking services, 3) game services available on the gaming machine

and 4) attract features. In one embodiment, a game input interface display is provided with a plurality of input buttons where a number and a format of the input buttons are dynamically configurable for different types of games of chance played on the gaming machine.

[0037] In FIG. 1A and 1B, a general layout of the thin light-emitting interface displays of the present invention are described. In FIG. 2, a gaming machine, it's operation, uses for the thin light-emitting interface displays and their locations on the gaming machine are described. In FIGS. 3A, 3B, 4A, 4B and 5, different embodiments of thin light-emitting interface displays of the present invention are described. In particular, in FIGS. 3A and 3B, a player tracking interface display that may be used to provide player tracking services is described. In FIGS. 4A and 4B, a game input interface display that may be used to provide player inputs for a game of chance is described. In FIG. 5, a game service interface display that may be used to provide game services on a gaming machine are described. In FIGS. 6 and 7, light emitting elements that may be used with the present invention are described. In FIGS. 8A-8D, touch and proximity sensors that may be used with the present invention are described. In FIGS. 9 and 10, block diagrams of gaming machine hardware that may be used to operate the thin light-emitting interface displays of the present invention are described.

[0038] In FIGS. 1A and 1B, block components of thin light-emitting interface displays 800 of the present invention are shown. The thin light-emitting interface displays 800 may be comprised of a number of layers that provide different functions. In FIG. 1A, four layers, a substrate 802, a light-emitting layer 804, a graphics layer 806 and a sensor layer 807 are shown. As will be described with respect to FIGS. 6 and 7, each of the four layers may comprise a number of sub-layers including a sub-layer substrate.

[0039] Sensor layer 807 may provide a matrix of sensors that are activated when an object touches an active sensor in the layer or an object is placed proximate to an active sensor in the sensor layer. The graphics layer 806 may be used to provide different graphical patterns to the interface display 800 such as a casino logo. The light emitting layer 804 may be comprised of a plurality of light emitting elements. The light emitting elements may be different colors and each lighting element may be independently controlled. The total thickness the sensor layer 807, the graphics layer 806 and the light emitting layer 804 may be on the order of microns.

[0040] The substrate layer 802 may be used to provide a support for the other layers. The substrate layer 804 may be rigid or flexible. The substrate 802 may not be separate from the other layers. For example, a substrate used to generate the light emitting layer 804 may also serve as a substrate for the interface display 800. In some embodiments, multiple substrate layers may be used.

[0041] Typically, the interface display 800 is mounted to an exterior surface of the gaming machine. Many different materials may be used in the exterior surface of the gaming machines. For instance, the exterior surface of the gaming machine may be laminated wood, plastic or metal. Further, the interface display 800 may cover a portion of the exterior surface of the gaming machine that is comprised of a plurality of materials. For instance, the portion of the exterior surface covered by the interface display 800 may be comprised of wood in a first area, plastic in a second area and metal in a third area.

[0042] In one embodiment, the substrate 802 may be integrated into the exterior surface of the gaming machine. For example, a rigid glass panel may be used as an exterior surface for the gaming machine. The rigid glass panel may also be used as a substrate 802 for the interface display 800. For instance, the light emitting layer 804 may be formed on one surface of the glass panel. The other layers may be formed above the light emitting layer or onto to the opposite surface of the glass panel. Then, the glass panel with the integrated interface display 800 may be installed on the gaming machine. Glass panels with different graphics patterns are often used on gaming machines. With the present invention, these glass panels may be replaced with glass panels integrated with the interface display 800.

[0043] The layers, 804, 806 and 808, are generally mounted to the substrate 802. For instance, an adhesive may be used to mount the light-emitting layer 804 to the substrate 802. The layers 804, 806 and 808 may also be mounted to each other. For instance, after the light-emitting layer is mounted to the substrate 802, the graphics layer 806 may be silk screened onto to the light-emitting layer 804 and the sensor layer may be bonded to the graphics layer 806 and the light emitting layer 804. In another example, the sensor layer 807, the graphics layer 806 and the light-emitting layer 804 may be bonded together within a plastic sleeve and the plastic sleeve may then be mounted to the substrate 802. In yet another example, a plastic cover may be laminated over layers 807, 806 and 804 to form a pillow-like configuration where the edges of the cover are laminated directly to the substrate 802.

[0044] The order of the layers in the interface display 800 may be varied from the order of the layers in FIG. 1A. For example, when the substrate 802 is clear or translucent to light, the light emitting layer 804 may be below the substrate 802, the graphics layer may be printed on either side of the substrate 802 and the touch screen layer may be the top layer 806. In another example, when the light emitting layer 804 is translucent, the graphics layer 804 may be printed onto the substrate 802, followed by either the light-emitting layer 804 with the sensor layer 806 on top or followed by the sensor layer 806 with the light-emitting layer 804 on top.

[0045] The present invention is also not limited to the number of layers in FIG. 1B. In one embodiment, stacks of different light emitting layers may be used. For example, a graphics layer 806 may be mounted to the substrate 802 followed by a light emitting layer 804, followed by a second graphics layer and then followed by a second light emitting layer with the sensor layer 807. In another example, in the layer configuration in FIG. 1A, the light emitting layer 804 may be comprised of a plurality of light emitting sub-layers.

[0046] The layer of the thin light-emitting interface display 800 may be arranged over a surface area of the interface display to perform different functions. Each layer of the interface display 800 may not be active over the entire surface area of the display. For example, lighting elements in the light emitting layer 804 may be patterned during their manufacture such that the elements only cover a portion of the interface display area 800. Therefore, the sensor layer

807 may be similarly patterned and may only be placed over the areas or only may be activated above the areas with active lighting elements.

[0047] In FIG. 1B, a block diagram of a surface layout for a thin light emitting interface display 80 is described for one embodiment of the present invention. The layers of the interface display may be arranged to form different devices over an interface display area 811. For example, a plurality of light emitting elements may be arranged in an output display matrix 810 to display alpha-numeric text and graphics. A sensor may be placed on top of the display matrix to provide input capabilities or the output display matrix 810 may simply be used as a display.

[0048] The surface layout may include input buttons 808 that are used to enter gaming information. The input buttons may comprise one or more active light elements and an active sensor. In one embodiment, a flexible substrate 802 may be used and the input buttons may be mounted over a raised surface on the exterior of the gaming machine (see FIG. 7). In another embodiment, a rigid substrate 802 may be used with raised surfaces and the other layers may be mounted over the raised surfaces to give the buttons a raised feel. The input buttons may also be mounted over indentations in a substrate 802 or over indentations in an exterior surface on the gaming machine. To allow for mounting over curved surfaces, the sensor layer 807 and the light emitting layer 804 may also be constructed on flexible materials.

[0049] In one embodiment, the active light elements on the input button may comprise layers of patterned electro-luminescent elements in the form of different symbols. The input button may be an area on the surface of the display with one or more sensors within the area. The sensors are used to detect a selection of the input area. A single electro-luminescent element may be used for a single symbol or a plurality of symbols such as a number of text symbols used to form a word.

[0050] The different symbols may be lit to provide a different meaning for the input button. For example, an input button may comprise electro-luminescent element with a "draw/hold" text pattern overlaid with a "play 1 line" text pattern. When the "draw/hold" pattern is lit, the input button may be used for a card game. When the "play 1 line" text pattern is lit, the input button may be used for a slot game. In a similar manner, a function of an input button may be changed by using an array of light emitting elements over the input button. Details of using electro-luminescent lighting elements patterned into different symbols that may be used with the present invention are described in U.S. Pat. No. 6,027,115, by Griswold, et al., issued Feb. 22, 2000 and entitled, "Slot Machine Reels having a luminescent display element," which is incorporated herein in its entirety and for all purposes.

[0051] The interface display 800 may include areas 809 with lighting elements arranged in patterns that are used to attract the attention of a player. For example, to attract the attention of a player, an array of lighting elements may flash in one or more different patterns. The interface display 800 may include areas 812 with lighting elements that are arranged to display information symbolically. For instance, when a device has malfunctioned on a gaming machine, a symbol of the device may be lit up on the interface display 800. As another example, when a player has requested a service, a service light with a service symbol may be lit up on the interface display 800.

[0052] Different portions of the interface display area 811 may be used to perform multiple functions. For example, the output display matrix 810 may be used to display information, input data, display attract graphics and used to display symbolic information. As another example, the symbolic display area 812 may be used to display various attract patterns when it is not being used to display symbolic information.

[0053] The sensors in the sensor layer 807 and the light emitting elements in the light emitting layer 804 may be controlled by one or more controller 814. In one embodiment, an integrated controller may be used to active the lighting elements and interpret signals from the sensors in the sensor layer 807. In another embodiment, separate controllers may be used for the sensors in the sensor layer 807 and the lighting elements in the lighting emitting layer 804.

[0054] As described with respect to FIG. 1A, the thin light-emitting interface displays of the present invention may be mounted to an exterior surface of a gaming machine. In FIG. 2, a video gaming machine 2 of the present invention is shown and the exterior surfaces are described. Machine 2 includes a main cabinet 4, which generally surrounds the machine interior (not shown) and is viewable by users. As described with respect to FIG. 1A, the thin light-emitting interface displays of the present invention may also be mounted within the interior of the gaming machine.

[0055] The main cabinet includes a main door 8 on the front of the machine, which opens to provide access to the interior of the machine. Attached to the main door are player-input switches or buttons 32, a coin acceptor 28, and a bill validator 30, a coin tray 38, and a belly glass 40. Viewable through the main door is a video display monitor 34 and an information panel 36. The display monitor 34 will typically be a cathode ray tube, high resolution flat-panel LCD, plasma monitor, OLED monitor or other conventional electronically controlled video monitor. A touch screen may be mounted over the display monitor 34 and game service interfaces may be displayed on the touch screen monitor.

[0056] The information panel 36 may be a back-lit, silk screened glass panel with lettering to indicate general game information including, for example, the number of coins played. The bill validator 30, player-input switches 32, video display monitor 34, and information panel are devices used to play a game on the game machine 2. The devices are controlled by a master gaming controller (see FIGS. 9 and 10) housed inside the main cabinet 4 of the machine 2. Many possible games, including traditional slot games, video slot games, video poker, video black jack, video keno, video pachinko, lottery games and other games of chance as well as bonus games may be provided with gaming machines of this invention.

[0057] The gaming machine 2 includes a top box 6, which sits on top of the main cabinet 4. The top box 6 houses a number of devices, which may be used to add features to a game being played on the gaming machine 2, including speakers 10, 12, 14, a ticket printer 18 which may print

bar-coded tickets 20 used as cashless instruments and devices used for player tracking such as display 22 and card reader 24. A secondary display 44, which may also include a touch screen, is mounted in the top box. The secondary display 44 may also be used to operate game service interfaces.

[0058] Typically, the thin light-emitting interface displays of the present invention are mounted to an exterior surface of the gaming machine viewable by the player and within easy reach of the player when they are facing the front of the gaming machine. Generally, the exterior surfaces satisfying these criteria are proximate to the display 34 although the present invention is not limited to these areas. The exterior surfaces where the interface displays are mounted may be orientated in a horizontal, vertical or angles in between horizontal and vertical, relative to the player's view. Further, the exterior surfaces where the interface displays are mounted may be flat, curved with a varying topology and combinations thereof. In one embodiment, a single thin interface display may be "wrapped" across two surfaces that are angle to one another. For example, the thin light-emitting interface display constructed on a flexible substrate may extend from the area 50 that borders the display 34 across the corner to the area 51 that is nearly perpendicular to area 50.

[0059] An interface display may be mounted around the player tracking devices 22 and 24. Embodiments of the thin light-emitting interface displays of the present invention that may be used with player tracking units are described with respect to FIGS. 3A and 3B. An interface display may be mounted to the nearly horizontal area where the input buttons 32 are located. Embodiments of a dynamically configurable interface display of the present invention that may be used to provide game inputs is described with respect to FIGS. 4A and 4B. An interface display for providing game services may be mounted to an available exterior surface on the gaming machine such as the information panel 36. Further, the interface display may be integrated into the available exterior surface such as the information panel 36. An embodiment of an interface display for providing game services is described with respect to FIG. 5.

[0060] The player tracking unit mounted within the top box 6 may include a touch screen display 22 for entering player tracking information, displaying player tracking information and displaying game service interfaces. The touch screen display 22 may be part of a thin light emitting display of present invention (see FIG. 3B). The player tracking unit also includes a card reader 24 for entering a magnetic striped card containing player tracking information and a speaker/microphone 42 for projecting sounds and inputting voice data. In addition, the player tracking unit may include additional peripheral interface devices such as biometric input devices (not shown).

[0061] Understand that gaming machine 2 is but one example from a wide range of gaming machine designs on which the present invention may be implemented. For example, not all suitable gaming machines have top boxes or player tracking features. Further, some gaming machines have two or more game displays - mechanical and/or video. And, some gaming machines are designed for bar tables and have displays that face upwards. Still further, some machines may be designed entirely for cashless systems. Such machines may not include such features as bill validators, coin acceptors and coin trays. Instead, they may have only ticket readers, card readers and ticket dispensers. As another example, a game may be generated on a host computer and may be displayed on a remote terminal or a remote computer. The remote computer may be connected to the host computer via a network of some type such as the Internet. Those of skill in the art will understand that the present invention, as described below, can be deployed on most any gaming machine now available or hereafter developed.

[0062] Returning to the example of FIG. 2, when a user wishes to play the gaming machine 2, he or she inserts cash through the coin acceptor 28 or bill validator 30. In addition, the player may use a cashless instrument of some type to register credits on the gaming machine 2. For example, the bill validator 30 may accept a printed ticket voucher, including 20, as an indicia of credit. As another example, the card reader 24 may accept a debit card or a smart card containing cash or credit information that may be used to register credits on the gaming machine.

[0063] Prior to beginning a game play session on the gaming machine 2, a player may insert a player tracking card into the card reader 24 to initiate a player tracking session. In some embodiments, after inserting their card, the player may be visually prompted on the display screen 22 or aurally prompted using the speaker to enter identification information such as a PIN code using a light emitting interface display of the present invention. Typically, the player tracking card may remain in the card reader 24 during the game play session. As another example, the gaming machine may transfer player tracking information from portable wireless device worn by the player via a wireless interface device (not shown) on the gaming machine 2. An advantage of using a portable wireless device is that the transfer of player tracking information is automatic and the player does not have to remember to correctly insert a player tracking card into the gaming machine.

[0064] In a player tracking session on the gaming machine, features of the player's game play during a game play session on the gaming machine, such as an amount wagered during the game play session, may be converted to player tracking points and stored in the player's player tracking account on a player tracking server. Later, accumulated player tracking points may be redeemed for rewards or for "comps" for the player such as free meals or free rooms. Usually, the player tracking card inserted into the card reader contains at least player tracking account information. When the card is inserted correctly into the card reader 24, the information stored on the card, such as the player's account information, may be read by the card reader and transferred by a logic device on the player tracking unit to a player tracking server. The player tracking account information allows the player tracking server to store player tracking points accumulated during the game play session to the appropriate account. When player tracking information is not provided by the player, for instance, when the player tracking card has been inserted incorrectly into the card reader 24 or the player is not a member of a player tracking program, player tracking points are not accumulated.

[0065] During the course of a game, a player may be required to make a number of decisions, which affect the

outcome of the game. For example, a player may vary his or her wager on a particular game, select a prize for a particular game, or make game decisions which affect the outcome of a particular game. The player may make these choices using the player-input switches 32, the video display screen 34 or using some other device which enables a player to input information into the gaming machine. Certain player choices may be captured by player tracking software loaded in a memory inside of the gaming machine. For example, the rate at which a player plays a game or the amount a player bets on each game may be captured by the player tracking software.

[0066] During certain game events, the gaming machine 2 may display visual and auditory effects that can be perceived by the player. These effects add to the excitement of a game, which makes a player more likely to continue playing. Auditory effects include various sounds that are projected by the speakers 10, 12, 14. Visual effects include flashing lights, strobing lights or other patterns displayed from lights on the gaming machine 2, from lights behind the belly glass 40 or the light panel on the player tracking unit 44.

[0067] After the player has completed a game, the player may receive game tokens from the coin tray 38 or the ticket 20 from the printer 18, which may be used for further games or to redeem a prize. Further, the player may receive a ticket 20 for food, merchandise, or games from the printer 18. The type of ticket 20 may be related to past game playing recorded by the player tracking software within the gaming machine 2. In some embodiments, these tickets may be used by a game player to obtain game services or as a receipt for game services provided on the gaming machine.

[0068] In an embodiment of the present invention, a portion of the exterior surface of the gaming machine may be covered with a dynamically configurable electro-luminescent "skin." The electro-luminescent skin may be comprised of a plurality of panels with matrices of electro-luminescent elements, such as matrices of OLED elements (see FIG. 7) mounted to the exterior surface of a gaming machine. Typically, the exterior surface of the gaming machine is painted with graphical patterns that match a theme of the game played on the gaming machine. The graphical patterns add to the personality of the gaming machine. However, the patterns are static and are not easily changed.

[0069] Using the dynamically configurable electro-luminescent skin, when a game is loaded onto to the gaming machine for game play, graphical patterns corresponding to the game may be displayed on the electro-luminescent skin. A first type of game may use one set of graphical patterns and a second game may use another set of graphical patterns. Also, the graphical patterns used for a particular game may vary with time. Further, graphical patterns, used as part of an attract mode, may also be generated on the electro-luminescent skin.

[0070] As an example, a dynamically configurable electro-luminescent skin may be mounted to 1) an exterior surface surrounding the secondary display 44 on the top box, 2) over and surrounding the belly glass 40 and 3) around the display screen 34 and 4) over the information panel 36. In one embodiment, the electro-luminescent skin, such as an OLED skin, may be used in lieu of the display screen 34 and/or the secondary display 44. Thus, the electro-luminescent skin may be mounted in the area occupied by the display screen 34 and/or the second display 44 rather than just surrounding these devices. In this embodiment, a first portion of the electro-luminescent skin may be used for displaying the game of chance, a bonus game or any other gaming information that is traditionally displayed on the display screen 34 and the secondary display 44. A second portion of the electro-luminescent skin may be used to display graphical patterns particular to the game of chance played on the gaming machine.

[0071] Game logic used to generate the different graphical patterns on the electro-luminescent skin may be stored in a memory device on the gaming machine. The game logic may be executed by the master gaming controller on the gaming machine. One or more controllers for the electro-luminescent skin may be used to generate the graphical patterns on the skin determined by the master gaming controller. Further, when a portion of the electro-luminescent skin is used as a display screen, the one or more controllers may be used to display video frame data.

[0072] FIGS. 3A and 3B are block diagrams of a player tracking interface display (PTID) 200 that are embodiments of a thin light-emitting interface display of the present invention. The PTID 200 may be mounted to a front face of a player tracking unit mounting within a gaming machine as described with reference to FIG. 1. The PTIDs of this invention may be designed as part of new player tracking units or as retrofits for existing player tracking units. For instance, a retrofit electro-luminescent PTID may be installed on a portion of the front face of an existing player tracking unit to convey additional player tracking status information.

[0073] An advantage of the PTIDs of the present invention is that additional capabilities may be added to the player tracking unit using only available surface area on the player tracking unit or proximate to the player tracking unit on the gaming machine. Since the interface displays have a small or no interior foot print, issues regarding packaging and thermal transfer are not as important as compared to conventional interface displays which makes retrofitting existing devices more feasible. For example, it might not be possible to retrofit an existing player tracking unit with a conventional display because there might not be room for the device within the interior of the player tracking unit.

[0074] Further, even if room for a conventional display were available, it may be simpler and cheaper to mount a thin light-emitting interface display to the exterior of the gaming machine than to retrofit the player tracking unit with a convention display. The retrofitting and installation of a player tracking device with a conventional display may involve developing mounting brackets, a new face plate and then opening up the player tracking device to make the changes. This process may be much more complicated than simply mounting the thin light-emitting interface display to the exterior of the player tracking device.

[0075] The PTID 200 allows a game player, service technician or other game service representative to input information into the player tracking unit and receive player tracking status information. The PTID 200 utilizes a number of electroluminescent elements that may display different colors and light patterns. The colors and light patterns may be used to highlight or emphasize various information

components to players and casino staff. The information can be but is not limited to, system and game communication status related to the status of the player tracking system, the gaming machine and peripheral equipment. For instance, drop/fill door open, jackpot pending, hopper empty and reel tilt signals may be conveyed as information in some format on the PTID 200.

[0076] The overlay for the thin light-emitting interface display may be any color or combination of colors. Information may be conveyed to the observer by a use of light intensity, color, light patterns, flash rate, textual messages and symbols/icons from the electro-luminescent elements within the light emitting layer. The electroluminescent elements may be a point source (i.e., a small area), such as an organic light emitting diode (OLED). OLEDs (see FIG. 7) use carbon based organic molecules that emit light via electro-luminescent when a charge is passed through the molecules. The electro-luminescent elements may also be manufactured in a shape such as alpha-numeric patterns or iconic patterns.

[0077] The electro-luminescent elements may overlay or surround various player tracking interface devices. The thin light-emitting interface displays may be manufactured with one or more cut-outs to allow the interface displays to surround one or more devices. For example, the light-emitting interface display may surround a card reader 24 or a display. Further, one or more electro-luminescent elements may be placed on top of one or more buttons on a key pad to illuminate each button. The interface display may be placed over or around the various devices during installation. The key pad may be used for inputting information back to the system, such as pin number security codes and jackpot validations, or signaling the casino staff as to requirements of the player and the gaming machine.

[0078] The configuration and types of interface devices in a player tracking unit may vary from unit to unit. For example, some player tracking units may include a bonus button while other player tracking units may not include this feature. In another example, the input device may be configured in a stacked configuration (e.g. a key pad, card reader and display may be arranged one above the other rather than side by side). Thus, the present invention is not limited to one type of PTID configuration and the PTID 200 is presented for illustrative purposes only.

[0079] Returning to FIG. 3A, a number of electro-luminescent elements and there functions are described. One element 201 may highlight a gaming system logo which may be a manufacturer name or a name of a casino. The name may be written in any number of text styles such as block letters or cursive and may include various symbols. One advantage of electro-luminescent lighting virtually any type of text style or symbol may be illuminated. The element 201 may be lit continuously using ½ power. The element 201 may be a single electro-luminescent element or may be comprised of a plurality lighting elements that may be independently controlled. The plurality of lighting elements may be flashed in different patterns as part of an attract mode to draw a player's attention to the gaming machine.

[0080] A card reader element 202 may be located approximate to the card reader. The card reader element 202 may be "on" until a card is inserted and then "off" after the card is inserted into a card reader. Each of the keys in the keypad, such as 203, may be lighted by one or more electro-luminescent lamps. The lamps may be off unit a card is inserted and then on after the card is inserted. A selection of the button 203 may be detected via a mechanical sensor that is activated when the button 203 is depressed. In another example, the selection of the button 203 may be detected via a sensor layer over the button 203 that is incorporated into the thin light-emitting interface display.

[0081] As described with respect to FIG. 1A, the electro-luminescent lamps may be stacked. For instance, a first electro-luminescent lamp may be formed in the shape of a "three" on button 203. A second electro-luminescent lamp may be stacked in layer above or below the "three" in another a shape of another pattern. The first and the second electro-luminescent lamps may be independently controlled. Therefore, when a charge is supplied to the first lamp and not the second lamp, the button 203 may be lit up with the pattern of the three and may be used to input the "three." When a charge is supplied to the second lamp and not the first lamp, the button 203 may be lit up with the pattern of the second lamp and may be used to input information according to the pattern on the second lamp.

[0082] A number of lamps may be used to indicate card status information. Typically, a magnetic striped card is used to input player tracking information. The card must be inserted correctly and operating properly to read the data. Card operation conditions may be conveyed via the PTID 200. For instance, an "invalid card" lamp 204, shown in a text format, may be turned on when an invalid card is inserted into the card reader and may remain on until the invalid card is removed. The text may be a particular color such as red to draw attention to the text. In addition, a light pattern may be used with the lamp 204. For instance, the lamp 204 may flash and remain flashing until the invalid card is removed. Although not shown, a graphical format (e.g. a symbol) and a combination graphical format and textual format may be also used to indicate an invalid card. For instance, a circle with a diagonal line across it may be placed over the "invalid card" test. The invalid card may be removed from the card reader by the player or a casino service representative. The card may be invalid because it has expired, was reported lost or stolen, has been demagnetized or may be the wrong type of card (e.g. from another casino).

[0083] A "good luck" lamp 205, shown in a text format, may be off until a card is inserted and then may remain on for a fixed period of time. For instance, the lamp may remain on for 10 seconds after a card has been inserted. A "stranded card" lamp 206 may be illuminated when a card has been inserted and the gaming machine has not been played for a particular amount of time (e.g. 10 minutes). The lamp 206 may remain flashing until the card is removed. For instance, when a player finishing a game play session and leaves the gaming machine while their card is still in the card reader, the stranded card lamp 206 may be activated. A casino service representative may spot the flashing light and remove the stranded card from the gaming machine and deposit it in a lost and found area at the casino. Once the card is removed the light is deactivated.

[0084] When the player tracking unit is malfunctioning for some reason, a service light 207 may be illuminated. For instance, the card reader may be working incorrectly. The

service light 207 may remain illuminated and may flash until a service button 212 is depressed on the PTID 200 by a service attendant. The service attendant may have to provide identification information such as entering a code using the key pad and clear the error before the service light 207 can be deactivated. Thus, a player would not be able to deactivate the service light 207 by depressing the service button.

[0085] During game play, a player may desire to order a drink or obtain some other service from a casino service representative. When the player presses a drink button 213, a border lamp 210 around the gaming system logo 201 may be illuminated and the service light 208 may be illuminated. The signal for a drink order may also be sent to a service bar. Using the key pad elements, a player may be to specify a drink order and have a casino service representative deliver it. In some embodiments, direct ordering of drinks may only be available to players with a special status as determined by the casino. A passing casino service representative may view these lights on the PTID 200 and take a drink order from the game player. These lights may remain on until the clear button 214 is depressed on the PTID 200.

[0086] The PTID 200 may display information regarding an amount won during a particular game play session. For instance, each of the four bars in lamp 209 may be illuminated after a certain incremental amount is won by the player. For instance, a first bar may be lit when the player has won 1000 coins, a second bar may be lit when the player has won 2000 coins, a third bar may be lit when the player has won 3000 coins, etc. Thus, the four bars may be independently controlled. The bar lights may be lit when the player has inserted a valid player tracking card in the card reader or when the player has not entered a valid player tracking card in the card reader.

[0087] The player may be able to initiate a player tracking point redemption at the gaming machine using the redeem points button 211. Using the key pad, the player may enter a pin code and a numerical amount of points. In one embodiment, the redeemed points function may be used to add credits to the gaming machine.

[0088] The status information indicated on the PTID 200 and configuration of the status information as described above is for illustrative purposes only. Additional status information may also be conveyed with PTIDs of the present invention. For instance, a player status such as valued customer status may be displayed on the PTID using an electro-luminescent lamp. As another example, other electroluminescent lamps may be provided to request different casino services such as a dinner or entertainment reservation. In yet another example, different electroluminescent elements may be illuminated to indicate printer status information, system control status and hopper status. Also, the lamps may be arranged in different manners. For instance, in one embodiment, a number of symbols may be arranged side by side in a row similar to a display panel on an automobile dashboard.

[0089] In FIG. 3B, a second embodiment of the PTID 200 is shown. Compared to the embodiment in FIG. 3A, a different electro-luminescent light pattern is used around the card reader 24. The bars 209, used to indicate an amount of credits won, are rearranged. The key pad is moved and resized. Further, the gaming system logo 210 is moved.

[0090] In the center of the PTID 200, the light-emitting layer includes a matrix of electro-luminescent elements that may be used as a display 221. In one embodiment, the display may include a 320x240 matrix of electro-luminescent elements such as OLED elements. The display may be a color or black and white display. Further, the display may be an active matrix or a passive matrix display. It may be used to display player tracking information, animations, bonus games, symbolic information, promotions, video frames and advertisements.

[0091] The display 221 may be overlaid with a sensor layer to allow the display to be used as an input device. The sensor layer may include a plurality of touch activated sensors or proximity sensors. The display is surrounded a bar with three electro-luminescent light elements 220. The light elements may be used to convey additional information to the game player. Details of player tracking units that may be used with PTIDs of the present invention and other gaming information (e.g., machine events), which may be conveyed by illumination devices of the present invention are described in co-pending U.S. application Ser. No. 09/921489, by Hedrick, et al., filed on Aug. 3, 2001, entitled "Player Tracking Communication Means in a Gaming Machine," which is incorporated herein in its entirety and for all purposes.

[0092] FIGS. 4A and 4B are block diagrams of a game input interface display (GIID) 700. The GIID 700 may be used to provide inputs for a game of chance played on the gaming machine. In one embodiment, the GIID 700 is separate from the main display on the gaming machine and may be located on the surface where mechanical input buttons are usually located on the gaming machine.

[0093] In one embodiment, the GIID 700 may comprise a sensor layer over a matrix of electro-luminescent elements. Different areas of the matrix may be activated to create input buttons for a game of chance. For instance, in FIG. 4A, input buttons for a "max bet"702, a "bet 1 credit"704, "cash out"706 and "start game"705 are shown. The max bet button may be used to make the maximum bet allowed on the gaming machine for a game of chance. The "bet 1 credit" may be used to bet a single credit on a game of chance. The "cash out"706 button may be used to cash credits out posted on the gaming machine. The "start game"705 button may be used to initiate the game of chance.

[0094] The text on buttons, 702, 704, 705 and 706, the light around the text, and the outline shape of the buttons may be generated using a number of electro-luminescent elements in the matrix. The text, light around the text and the outline shape of the buttons may all change with time by controlling the electro-luminescent light elements in the matrix. For instance, the text may change styles and change colors over time. In another embodiment, the shape of the buttons may change with time, such as from rectangular to circular. In yet another embodiment, animations and other patterns may be shown on the buttons. Further, the position and size of the buttons may be varied by shifting the light elements used to generate the button and by using more or less elements to generate the button. In another embodiment, a language used on the buttons, such as English, German, Japanese or French, may be selected by the player.

[0095] Input buttons may be configured that are used to provide inputs for a particular type of game of chance. For instance, five buttons, 710, 711, 712, 713 and 714 are generated that are used to hold or draw cards in a five-card

hand poker game. For card games that require more cards, additional hold/draw buttons may be generated. For card games that require less than five cards, fewer hold/draw buttons may be defined.

[0096] The game input interface display may be configured for different types of games. For example, in FIG. 4A, input buttons for a card game are generated. As another example, in FIG. 4B, input buttons are generated for a slot game. For slot game, input buttons, 715, 716, 717 and 718 are generated. When activated, input buttons 715, 716 and 717 allow a game player to play 1 payline, 3 paylines or 5 paylines in a slot game. The start game button 705, used in FIG. 4A, is not used. Instead, a spin button 718 may be used to initiate the game of chance.

[0097] In one embodiment of the present invention, different games of chance may be played on the same gaming machine. The games of chance may be selected by a player or an operator of the gaming machine. For each type of game of chance that may be played on the gaming machine, a unique game input interface display may be generated. The game input interface display may include but is not limited 1) a number of input buttons, 2) text/graphical information displayed for each button, 3) a color, a shape, a size and position for each button and 4) patterns and colors surrounding the buttons. In addition, metering information such as a number of credits or a progress in a bonus game may be displayed on the game input interface display 700.

[0098] When the game of chance that is played on the gaming machine is changed, the GIID 700 may be changed. For example, during game play session on the gaming machine comprising a plurality of games, a player may first choose to play a card game using the GIID 700 in FIG. 4A. Then, the player may choose to play a slot game and the GIID 700 may be configured to the layout shown in FIG. 4B.

[0099] In another embodiment, the game input interface display may be configured for other gaming machine functions. For instance, when internet or a messaging service is provided on a gaming machine, the GIID may be configured to display a text keyboard. In another example, a maintenance/diagnostic input configuration may be generated when the gaming machine for maintenance procedures performed on the gaming machine.

[0100] In yet another embodiment, the matrix of electro-luminescent elements may only occupy a number of areas of the GIID 700. In FIGS. 4A and 4B, since the "max bet" button 702, 704 and 706, these buttons may be generated using electroluminescent elements in the shape of the text on the buttons (see FIG. 6) and a matrix of electro-luminescent elements may not be used. For this type of lamp element, the text on the buttons defined by the shape of the lamp may not be changed.

[0101] A number of electro-luminescent element matrices may be placed at the locations of buttons 710, 711, 712 and the region 720. For instance, a small matrix of elements may be generated that allow a number of text characters to be generated on the buttons. The outline of the buttons may be generated using a graphics layer. Using the lamp matrices defined at the location of each button, the text on the buttons may be changed. For example, "hold/draw" text in button 710 may be changed to the "1 payline," text in 715. However, the position or the shape of the button may not be changed.

[0102] A larger electro-luminescent lamp matrix is located in region 720. With this matrix, a number of buttons may be changed. For example, two "hold/draw" buttons, 713 and 714, are shown in FIG. 4A. In FIG. 4B, a single "spin" button 718 is drawn with the matrix in region 720. The size of the single spin button 718 is larger than the size of each of the hold/draw buttons, 713 and 714.

[0103] FIG. 5 is a block diagram of a game service interface display (GSID) 250 using a thin light-emitting interface display of the present invention. The format of the GSID 250 is provided for illustrative purposes only. The GSID 250 comprises a 16 character display 254, a nine button key pad with number buttons such as 251, two function buttons, 212 and 213, an enter button, a forward button 252, a back space button 253 and a clear button 214. The display 254 may be comprised of a plurality of electro-luminescent elements such as OLEDs that are individually controlled. For example, each character of the 16-character display may include 7 light-emitting elements. The elements of in each character of the display 254 may be activated in different patterns to generate a number of alpha-numeric symbols. The present invention is not limited to a 1-line 16 character display. Displays that allows multiple lines of text to be displayed with a greater number of characters in each line may be used with the present invention. For instance, the GSID 250 configuration in FIG. 5 may be generated from a matrix of electro-luminescent elements similar to one embodiment of the game input interface display described with respect to FIGS. 4A and 4B.

[0104] The key pad buttons with the back space and forward keys may be used to enter numbers and text. The buttons may include a sensor layer used to detect when the buttons have been activated. The buttons and display 254 may be used to send and/or receive text messages to/from other game players and casino personnel. The text that is input via the GSID 250 or received text from another device may be displayed on the display 254. For example, using the GSID 250, a player may be able to request a drink and enter a specific type, such as a "beer," which may be sent to a drink station at the casino. In another example, the GSID 250 may be used to send a text message to another device using a text messaging system. The GSID 250 may be connected to a gaming/phone network that allows the gaming machine to send messages to other devices such as cell phones, pagers and other gaming machines and receive messages from these gaming devices.

[0105] In other embodiments, the GSID 250, in the layout in FIG. 5 or in a different layout, may be used by a player to: 1) input player tracking identification information, 2) view account information and perform account transactions for accounts such as player tracking accounts and bank accounts, 3) receive operating instructions related to the player tracking unit and the gaming machine, 4) redeem prizes or comps including using player tracking points to redeem the prize or comp, 5) make entertainment service reservations, 6) transfer credits to cashless instruments and other player accounts, 7) participate in casino promotions, 8) select entertainment choices for output via video and audio output mechanisms on the player tracking unit and the gaming machine, 9) play games and bonus games, 10) perform numerical calculations using the interface as a calculator and 11) register a player for a loyalty program such as a player tracking program. In addition, the GSID 250

may be used as an interface by casino service personnel to: a) access diagnostic menus, b) display player tracking unit status information and gaming machine status information, c) access gaming machine metering information and d) display player status information. Details of game service interfaces for the game services listed above, such as interface formats, which may be used in the present invention, are described in co-pending U.S. application Ser. No. 09/961,051, filed on Sep. 20, 2001, by Paulsen, et al., and entitled, "Game Service Interfaces For Player Tracking Touch Screen Display" which is incorporated herein in its entirety and for all purposes.

[0106] Some of the input buttons, such as 211, 212, 213 and 214 were also used in the player tracking interface display described with respect to FIGS. 4A and 4B. One advantage of the GSID 250 in FIG. 5 is that it does not have to be connected to a player tracking system or used in conjunction with a player tracking system. Thus, the gaming services usually provided through a player tracking system may be provided through the GSID 250 without the use of a player tracking system.

[0107] Another advantage of the GSID 250 is that it may enable an easier installation of the player tracking unit on the gaming machine. With a traditional player tracking unit, mounting brackets, a cabinet and a faceplate are required that allow the devices in the player tracking interface unit, such as key pad, display and card reader to be secured to the gaming machine. Then, a location must be found on exterior surface of the gaming machine for the player tracking unit that is accessible to the player and that may accommodate the interior footprint of the player tracking unit cabinet.

[0108] The size of the interior foot print of the player tracking cabinet limits the location where it may be placed on the gaming machine. Typically, the gaming machine components are tightly packaged to minimize the foot print of the gaming machine on the casino floor. Therefore, on older gaming machines, a top box (see FIG. 2) that includes additional space may be added to the gaming machine to allow for the installation of the player tracking unit. The GSID 250 may have a small or no interior footprint. For instance, in one embodiment, it may be mounted to an exterior surface or integrated into the exterior surface of an available area on the gaming machine such as the informational panel 36 (see FIG. 2). Since the GSID 250 may be used as a key pad and display for the player tracking unit, the interior footprint of a player tracking unit cabinet may be reduced from a size needed to accommodate the key pad, the display and a card reader to a size needed only to accommodate the card reader. Therefore, with size of the player tracking unit reduced, more locations on the gaming machine may be available that satisfy the interior space requirements needed to install the player tracking unit.

[0109] FIGS. 6A and 6B depicts an electro-luminescent portion 400 of the player tracking interface display 200 shown in FIG. 3A in greater detail. FIG. 6A presents a top view of symbol section 400 with three symbol regions 413, 415 and 417. In this embodiment, the individual light elements on the symbol regions of cross section 400 are electro-luminescent elements. Each electro-luminescent element is defined by a capacitor having two "conductive" plates and an electro-luminescent dielectric sandwiched there between. Each electro-luminescent element in symbol section 400 are independently controllable. Thus, separate lines are provided to at least one of the conductive plates of each such element.

[0110] In the embodiment depicted, one plate is provided by a continuous strip of conductive material. This strip includes trace segments 405 connecting individual conductive plates 407, 409 and 411 in adjacent symbol regions 413, 415, and 417. While not depicted in FIG. 3A, traces 405 may connect additional conductive plates distributed along the player tracking interface display 200.

[0111] To simplify the illustration, electro-luminescent elements are not explicitly depicted in FIG. 6A. The electro-luminescent material associated with the symbols in regions 413, 415, and 417 define the shape of the symbol items themselves. Thus for example in region 413, the electro-luminescent dielectric element defines the one-key symbol shown. Similarly, in region 415, the electro-luminescent dielectric defines a four-key symbol and in region 417, the electro-luminescent dielectric defines a seven-key symbol.

[0112] The individual electro-luminescent elements in the various symbol regions are independently controlled by separate traces 421A-C. Each of these traces terminates in a conductive plate associated with the electro-luminescent element it controls. For example, trace 421A terminates in a conductive plate 423 which controls illumination of the one-key symbol in region 413. For example, trace 421A terminates in a conductive plate 423 which controls illumination of the one-key symbol in region 413, trace 421B terminates in a conductive plate 426 which controls illumination of the four-key symbol in region 415, and conductive trace 421C terminates in a capacitor plate 427 which controls illumination of the seven-key symbol in region 417. Preferably, the conductive traces 421 and the capacitor plates that they terminate in are made from a conductive yet transparent material. One such material is indium tin oxide.

[0113] FIG. 6B presents a cross-sectional view of symbol section 400. As shown, section 400 includes a polymeric substrate 450 made from a flexible material such as polyester. The total thickness of the cross section may be about 10-50 microns depending on the materials used. A conductive layer such as aluminum is formed on substrate 450. This layer is patterned to comprise traces 405 and lower capacitor plates such as plate 407. Next, an isolation layer 455 is formed over substrate 450 including traces 405 and capacitor plate 407. Isolation layer 455 is then patterned to define electro-luminescent regions. Within these regions, electro-luminescent dielectric elements such as element 453 are formed. On top of this structure, traces 421 and capacitor plates such as plate 423 are formed. Again, this material is preferably a transparent conductor such as indium tin oxide. This layer should be transparent so that light generated from electro-luminescent elements such as element 453 will be visible to the gaming machine player.

[0114] The entire electro-luminescent capacitor structure described until now may be covered with a printed cover strip 457. This cover strip may be transparent except where inked symbol images have been printed. Preferably, such images are silk screened onto cover strip 457. In addition, cover strip 457 may be made from a flexible material such as Mylar. The cover strip is an example of a graphics layer 806 described with respect to FIG. 1A.

[0115] FIG. 7 is a block diagram of an Organic Light Emitting Diode (OLED) 450 that may be used with the

present invention. The basic OLED cell structure 450 consists of a stack of thin organic layers 453 sandwiched between a transparent anode 452 and a metallic cathode 454. The OLED cell structure 450 may be used to form a pixel in a thin light-emitting interface display of the present invention.

[0116] The organic layers 453 may comprise a hole injection layer, a hole-transport layer and an electron-transport layer. The structure of the organic layers 453 and the choice of the anode 452 and cathode 454 are selected to maximize the recombination process in the emissive layer, thus, maximizing the light output from the OLED device. When an appropriate voltage is applied, such as via leads 455 and 456, the injected negative and positive charges recombine in the emissive layer to produce light (electro-luminescence). A voltage range of 2-10 Volts Direct Current is a typical voltage range.

[0117] In one embodiment, an OLEDs may be fabricated on a transparent substrate 451, such as glass, on which the anode 452, such is indium-tin-oxide (ITO), is deposited. ITO is both conductive and transparent. Then, one or more organic layer may be coated to the ITO by thermal evaporation in the case of small organic dye molecules or spin coating in the case of polymers. In addition, to the luminescent layer, other organic layers may be used to enhance injection and transport of electrons and/or holes. The total thickness of the organic layers may be on the order of 100 nm. A metal cathode 454 may be evaporated on top of the organic layers 453. The method cathode may be formed from magnesium-silver alloy, lithium-aluminum or calcium. The cathode material may be selected for their low work functions in order that they provide efficient injection of electrons. The two electrodes, 452 and 454, may add about 200 nm to the total thickness of the device 450. Therefore, the overall thickness of the structure is mostly due to the thickness of the substrate 451.

[0118] The total thickness of a display manufactured with a matrix of OLED elements may be less than a 1 mm thick when a plastic substrate 451 (e.g., 0.18 mm) is employed and less than 2 mm thick when a glass substrate is used (e.g. 1.8 mm). The substrate 451 may be different than the substrate 802 described with respect to FIG. 1A, which was an exterior surface of the gaming machine. In one embodiment, the substrate 451 may be used to form an exterior surface of the gaming machine. Therefore, substrates 451 and 802 may be the same. Eastman Kodak Corporation (Rochester, N.Y.) and Universal Display Corporation (Ewing, N.J.) manufacturer OLED displays that may be used with the present invention.

[0119] In one embodiment of the present invention, the substrate 451 may be a flexible material such as an optically-clear plastic film or a reflective metal foil. With a flexible substrate, the OLED display may be conformed onto another shape, such as an exterior surface of a gaming machine. In some cases, an OLED display may be laminated to the exterior surface of the gaming machine. For instance, OLED displays on flexible substrate may be bent or rolled up. Using a flexible substrate, the OLED display may be less breakable and more impact resistant as compared to a rigid substrate such as glass which may be important for use in a gaming environment such as a casino.

[0120] In one embodiment, the OLED cell structure 450 may be relatively transparent. Therefore, the cell 450 may emit light through the top layer (i.e., the cathode 454) or through the bottom layer (i.e., the substrate 451) or through the top and bottom. When the OLED cell structure is transparent and emits light through the top cathode layer 454 than it may be used on top of opaque substrates such as metal, foils and wood that may form the exterior surface of a gaming machine.

[0121] The OLED pixel elements in matrix may be controlled as a passive matrix or an active matrix. Passive matrix displays consist of an array of light elements or pixels deposited on a patterned substrate in a matrix of rows and columns. In an OLED display, each pixel is an organic light emitting diode, formed at the intersection of each column and row line. To illuminate any particular pixel in the passive matrix, electrical signals are applied to the row line and column line of the pix. The brightness of a pixel may be controlled by increasing or decreasing the current supplied to the pixel.

[0122] An external controller circuit may be used to provide the necessary input power, video data signal and multiplex switches for the passive OLED display. Data signal is generally supplied to the column lines and synchronized to the scanning of row lines. When a particular row is selected, the column and row data lines determine which pixels are lit. A video output on the display is displayed by scanning through all the row successively in a frame time. A frame time is typically on the order of 1/60 of a second.

[0123] In an active matrix OLED display like the passive matrix, the array of pixels is divided into a series of row and column lines, with each pixel formed at the intersection of a row and column lines. However, each pixel consists of OLED in series with a thin film transistor (TFT). The TFT is a switch that may be used to control the amount of current flowing through the OLED. In an active matrix OLED display, information is sent to the transistor in each pixel, indicating a brightness level for the pixel. The TFT stores this information and continuously controls the current flowing through the OLED it controls. This method tends to reduce the power level required to operate the display as compared to a passive matrix display. The TFT may be manufactured on Polysilicon and integrated into the display.

[0124] FIGS. 8A-8D are block diagrams of sensor layers mounted to light-emitting layers for some embodiments of the present invention. In FIG. 8A, two light emitting layers are shown, a light emitting surface 105 and a light emitting surface 110 with a length to height ratio of about 4 to 3. The light emitting surfaces 105 and 110 may be comprised of a matrix of electro-luminescent diodes, such as OLEDs, as described of with respect to FIG. 7, electro-luminescent lamps in varying shapes as described with respect to FIG. 6 and combinations thereof. The display surface is not limited to a rectangular shape. A sensor layer may use circular, ovular and irregularly shaped light emitting surfaces. In one embodiment of the present invention, a color OLED display screen with a 3.5 inch diagonal and a resolution of 320 pixels by 240 may be used with a touch sensor layer as a touch screen display.

[0125] In FIGS. 8B-8D, three embodiments of different types of sensor layers, a resistive based touch screen (FIG. 8B), a capacitive based touch screen (FIG. 8C) and a surface acoustic wave touch screen (FIG. 28) are described. In FIG.

8B, an embodiment of a resistive touch screen 611 integrated with a display 610 is shown. In a resistive touch screen 611, a suitable substrate 620, such as glass or a flexible material, is coated with a clear conductive material 618. Polyester spacer dots 616 are used to separate a polyester cover sheet 612 from the substrate 620 with the conductive material coating 618. An inner surface of the polyester cover sheet 612 in contact with the polyester spacer dots 616 is coated with a conductive metal coating 614. An outer surface of the polyester cover sheet may be covered with a scratch resistant coating (not shown). The substrate 620 and other layers may be integrated into a touch screen assembly that may be mounted over the display 610 using an adhesive epoxy or some other mounting means. In another embodiment, the sensor layers may be directly mounted to the display surface 610.

[0126] A touch screen controller (not shown) is used to apply a small voltage gradient across the x-axis 611 of the substrate 620 and across y-axis 613 of the cover sheet 612 which produces a small current in the panel and the cover sheet. With a voltage applied to the substrate 620 and cover sheet 612, the layers of the resistive touch screen may be used as a sensor. When a stylus or other implement is used to press the conductive layers, 614 and 618, together, the current flowing across the substrate 620 and the cover sheet is altered. Based on the change in current, the touch screen controller determines the x and y coordinates of the stylus contact.

[0127] In FIG. 8C, an embodiment of a capacitive touch screen 630 integrated with a light emitting surface 610 is shown. In a capacitive touch screen 630, a substrate 136, such as a glass panel or a flexible material, is coated on both sides with a clear conductive material, 634 and 638. The inner conductive layer 638 may be primarily used for shielding. The outer surface of the touch screen may be a scratch resistant coating 632. Electrodes 639 are uniformly distributed around the edge of the touch screen 630 to apply a low-voltage field uniformly across the outer conductive layer 634. When a finger or a conductive stylus contacts the screen 632, a capacitive coupling occurs with voltage field which causes a small current to be drawn into the finger or the stylus. The current flow from the corners of the touch screen electrodes 639 are measured. The measured current flow is used by the touch screen controller (not shown) to determine the location of the contact on the screen.

[0128] In FIG. 8D, an embodiment of a wave touch screen mounted to a light emitting surface 610 is shown. The screen 644 may be an uncoated glass panel or another suitable substrate material. In one type of wave touch screen, transducers 642 in the corners produce ultrasonic waves on the glass panel. The reflectors 645 are used to create a standing wave pattern on the glass panel 644. When a soft-tipped stylus is touched to the surface of the panel 644, the transducers detect the attenuation of the wave, which may be used by a touch screen controller to determine the coordinates of the stylus. In an infrared touch screen, light emitting diodes and photoresistors on the edge of the screen are used to create a grid of infrared beams. A stylus or finger may be used to obstruct the beams and the touch screen controller determines the coordinates of the obstruction.

[0129] For most embodiments of the present invention, a capacitive based touch screen is preferred but the present invention is not limited to capacitive based touch screens. Capacitive touch screens are very clear, durable and have a high resolution. However, capacitive touch screen are generally more expensive than resistive touch screens. Further, when a finger is used as a stylus on a capacitive touch screen, a small amount of current is drawn into to the finger, which some game players may find annoying. Thus, in some embodiments, other touch screen types, such as a resistive touch screen or a wave touch screen, may be employed with the present invention.

[0130] The touch screen controller processes signals from the touch screen sensor and passes touch screen event data to one or more gaming devices that utilize the touch screen event data. For instance, the x and y coordinates of a contact point on the touch screen may be used be a processor on a player tracking unit, a master gaming controller or combinations thereof, to allow a user to navigate through a game service interface (see FIG. 5) and to enter gaming information. In general, a logic device in communication with the touch screen, such as the processor on the player tracking unit or the master gaming controller, uses a device driver to receive touch screen event data from the touch screen controller. The touch screen controller may be integrated into the sensor layers as another layer using thin-film circuit technology such as the thin film transistors described with respect to FIG. 7.

[0131] FIG. 9 is a block diagram of a player tracking system and a gaming machine with interface displays of the present invention. The player tracking unit 107 may be mounted to gaming machine 2 and may be connected to the player tracking server 120 in player tracking system 500. The player tracking unit includes a player tracking controller 501. The player tracking controller 501 may be a logic device, such as a microprocessor that controls the operation of the player tracking unit 107 and communicates with the player tracking server 120 and the master gaming controller 104.

[0132] The player tracking controller 501 may also communicate with other remote devices such as a terminal at a service bar used to receive drink orders. In response to player tracking events detected by the player tracking controller 501, such as a card inserted incorrectly or an invalid card, the player tracking controller 501 may send commands to an electro-luminescent lamp controller 502 to perform different functions, such as illuminate the "card invalid" lamp on the player tracking interface display 200 as described with the respect to FIGS. 3A and 3B.

[0133] The lamp controller 502 converts the command into voltages and signal patterns for one or more lamp elements 503 affected by the command. For example, the lamp controller 502 may provide a voltage level for the "card invalid" lamp that varies with time causing the "card invalid" lamp to light up and flash. As another in response to an "attract mode" command by the player tracking controller, the lamp controller may send phased voltage signals to a number of lamp elements 503 in the player tracking interface display causing the lamp elements to flash in sequence.

[0134] As described with respect to FIG. 7, the lamp controller 502 may control a matrix of electro-luminescent elements on a display screen. In this case, the lamp controller 502 may be used to generate signals as part of video

frame data displayed on the display. The player tracking interface display may include a plurality of lamp controllers, such as a lamp controller used to control an active matrix or passive matrix of OLEDs and a lamp controller used to control one or more electro-luminescent lamps formed in a shape of a symbol (see FIG. 6).

[0135] The player tracking controller 501 may receive input signals detected from a touch screen controller 504 connected to a plurality of touch sensors or proximity sensors 505. The input signals may be generated when an input button on the player tracking interface display 200 is activated. The input signals may be used to provide game services that are available through the player tracking system 500.

[0136] As described with respect to FIGS. 4A, 4B and 5, the gaming machine may include a game input interface display 700 and a game service interface display 250 that are controlled by the master gaming controller 504. The master gaming controller may control the lamp elements 507 on the game input interface display 700 via the lamp controller 502 and may receive input from sensors in the display 700 via the touch screen controller 104. Similarly, the master gaming controller may control the lamp elements 509 on the game service interface display 250 via the lamp controller 502 and may receive input from sensors in the display 250 via the touch screen controller 504.

[0137] The player tracking unit 107 may include one or more non-proprietary peripheral communication connections, such as a USB-compatible communications connection or a Firewire compatible communications connection. The player tracking controller 501 may be designed or configured to communicate with the master gaming controller 104 and the player tracking devices, such as a card reader and the player tracking interface display 700, using the non-proprietary peripheral communication connection, such as an USB connector, and using a non-proprietary communication protocol, such as USB. Details of using the non-proprietary peripheral communication connection are described in co-pending U.S. Pat. No. 6,251,014, filed Oct. 6, 1999, by LeMay, et al., entitled, "STANDARD PERIPHERAL COMMUNICATION," which is incorporated herein in its entirety and for all purposes.

[0138] In one embodiment, the master gaming controller 104 and the player tracking controller 501 may communicate with the different interface displays using both wired and wireless communications. For instance, the master gaming controller 104 may communicate with the touch screen controller 504 in the game input interface 700 via a wire USB-compatible connector and using a USB communication protocol. However, the master gaming controller 104 may communicate with the touch screen controller 504 in the game service interface display 250 using a wireless communication protocol such as Bluetooth, IrDA, IEEE 802.11 a, IEEE 802.11b, IEEE 802.11x (e.g. other IEEE 802.11 standards such as IEEE 802.11c, IEEE 802.11d, IEEE 802.11e, etc.), hiperlan/2, and HomeRF. The use of a wireless communicate protocols in the thin light-emitting interface displays of the present invention may simplify the installation process on the gaming machine by allowing the interface display to be installed without having to run wires to the master gaming controller.

[0139] FIG. 10 is a block diagram of a number of gaming machines with player tracking units connected to a player tracking server. The DCU 106, which may be connected to up to 32 player tracking units as part of a local network in a particular example, consolidates the information gathered from player tracking units in gaming machines 100, 101, 102 and 103 and forwards the information to the player tracking account server 120. The player tracking account server is designed 1) to store player tracking account information, such as information regarding a player's previous game play, and 2) to calculate player tracking points based on a player's game play that may be used as basis for providing rewards to the player.

[0140] The player tracking unit 107 communicates with the player tracking server via the SMIB 103, a main communication board 110 and the data collection unit 106. The SMIB 103 allows the player tracking unit 107 to gather information from the gaming machine 100 such as an amount a player has wagered during a game play session. This information may be used by the player tracking server 120 to calculate player tracking points for the player. The player tracking unit 107 is usually connected to the master gaming controller 104 via a serial connection of some type and communicates with the master gaming controller 104 using a communication protocol of some type. For example, the master gaming controller 104 may employ a subset of the Slot Accounting System (SAS protocol) developed by IGT of Reno, Nev. to communicate with the player tracking unit 107.

[0141] The master gaming controller 104 is in communication and may control the display 34, the game input interface display 700, and the game service interface display 250. The master gaming controller 104 and the player tracking controller 501 may communicate via the communication board 110. The player tracking controller 501 is in communication and may control the card reader 24 and the game service interface display 250. In one embodiment, the master gaming controller 104 and player tracking controller 501 may share the game service interface display 250. Further, as was described with respect to FIG. 5, the game service interface display 250 is not mounted on the front face of the player tracking unit. It is mounted on a gaming machine exterior surface and connected via a wired or wireless connection to the player tracking controller 501.

[0142] Although the foregoing invention has been described in some detail for purposes of clarity of understanding, it will be apparent that certain changes and modifications may be practiced within the scope of the appended claims. For instance, while the gaming machines of this invention have been depicted as upright models having top box mounted on top of the main gaming machine cabinet, the use of gaming devices in accordance with this invention is not so limited. For example, gaming machine may be provided without a top box or the gaming machine may be of a slant-top or a table top design.

What is claimed is:

1. An interface display for inputting and outputting gaming information on a gaming machine, the interface display comprising:

a substrate;

a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information;

a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements;

a plurality of sensors for detecting selections of the input areas; and

one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors.

2. The interface display of claim 1, wherein the thickness of the interface display is less than about 3 mm.

3. The interface display of claim 1, wherein the thickness of the light emitting layer is less than about 1 micron.

4. The interface display of claim 1, wherein the substrate is formed from a flexible material.

5. The interface display of claim 1, wherein the flexible material is selected from the group consisting of a plastic film and a metal foil.

6. The interface display of claim 1, wherein the substrate is glass.

7. The interface display of claim 1, further comprising:

a plurality of patterns formed in a graphics layer where the plurality of patterns are illuminated by one or more of the electro-luminescent elements.

8. The interface display of claim 7, wherein a portion of the patterns are used to display gaming information.

9. The interface display of claim 7, wherein a shape of the patterns is selected from the group consisting of a symbol, an icon, a logo, a word and an alpha-numeric text symbol.

10. The interface display of claim 7, wherein the one or more of the patterns is located in the input areas.

11. The interface display of claim 1, wherein a portion of the electro-luminescent elements are a matrix of organic light emitting diodes (OLEDs) wherein each OLED forms a pixel in the matrix.

12. The interface display of claim 11, wherein the OLED pixels in the matrix are controlled in an active matrix, a passive matrix and combinations thereof.

13. The interface display of claim 11, wherein groups of OLED pixels are controlled to display symbols, icons, logo, alpha-numeric text and video frame data.

14. The interface display of claim 1, wherein a matrix of electro-luminescent elements is located in one or more of the input areas.

15. The interface display of claim 14, wherein the matrix of electro-luminescent elements is used to generate a plurality of patterns in the one or more input areas.

16. The interface display of claim 15, wherein a first pattern generated by the matrix of electro-luminescent elements in a first input area is used to display a first type of gaming information and wherein a second pattern generated by the matrix of electro-luminescent elements in the first input area is used to display a second type of gaming information.

17. The interface display of claim 15, wherein a first pattern generated by the matrix of electro-luminescent elements in a first input area is used to display a first type of gaming information in a first language and wherein a second pattern generated by the matrix of electro-luminescent elements in the first input area is used to display the first type of gaming information in a second language.

18. The interface display of claim 1, wherein the plurality of electro-luminescent elements are arranged in a plurality of stacked layers.

19. The interface display of claim 18, wherein the electro-luminescent elements in each of the stacked layers are arranged in different patterns.

20. The interface display of claim 19, wherein a first pattern is displayed by activating the electro-luminescent elements in a first layer of the stacked layers and wherein a second pattern is displayed by activating the electro-luminescent elements in a second layer of the stacked layers.

21. The interface display of claim 1, wherein a light intensity of each electro-luminescent element is controlled by an amount of current supplied to each electro-luminescent element.

22. The interface display of claim 1, wherein gaming information is conveyed by the electro-luminescent elements using a light intensity, a color pattern, a light pattern, a flash rate and combinations thereof.

23. The interface display of claim 1, wherein one or more of the input areas are for inputting player tracking information.

24. The interface display of claim 1, wherein a portion of the input areas are for inputting gaming information for playing a game of chance on the gaming machine.

25. The interface display of claim 24, wherein the portion of the input areas for inputting gaming information for playing the game of chance are dynamically configurable to display different input selections used by different types of games of chance played on the gaming machine.

26. The interface display of claim 1, wherein a portion of the input areas are used to input gaming information for providing a game service on the gaming machine.

27. The interface display of claim 26, wherein the game service is selected from the group consisting of i) viewing account information, ii) performing account transactions iii) receiving operating instructions for the gaming machine, iv) redeeming prizes or comps, v) making entertainment service reservations, vi) participating in casino promotions, vii) selecting entertainment choices for output via video and audio output mechanisms on the gaming machine, viii) playing games and bonus games, ix) performing numerical calculations, x) accessing diagnostic menus, xi) displaying player tracking unit status information, xii) displaying gaming machine status information, xiii) accessing gaming machine metering information and xiv) displaying player status information.

28. The interface display of claim 1, wherein the interface display is operable to vary a number of input areas, a shape of an input area, a size of on an input area, a color of an input area and combinations thereof.

29. The interface display of claim 1, wherein one or more of the electro-luminescent elements is formed in a shape of a pattern.

30. The interface display of claim 1, wherein the shape of the pattern is selected from the group consisting of a symbol, an icon, a logo, an alpha-numeric text symbol and a word.

31. The interface display of claim 1, wherein the plurality of sensors are formed in a sensor layer and are activated by at least one of contact with an object and a proximity of an object.

32. The interface display of claim 31, wherein the sensor layer is at least one of a capacitive touch screen, a resistive touch screen, a wave touch screen and combinations thereof.

33. The interface display of claim 31, wherein the object is at least one of a finger and a stylus.

34. The interface display of claim 1, wherein the interface display is mounted to an exterior surface of the gaming machine.

35. The interface display of claim 1, wherein interface display is mounted to an exterior face of a player tracking unit on the gaming machine.

36. The interface display of claim 1, wherein the interface display is integrated into an exterior surface of the gaming machine.

37. A gaming machine comprising:

a gaming machine cabinet;

a master gaming controller for controlling one or more games of chance played on the gaming machine located within the interior of the gaming machine;

a main display for displaying the game of chance;

an interface display for inputting and outputting gaming information mounted to an exterior surface of the gaming machine cabinet, in communication with the master gaming controller and separate from the main display, said interface display comprising:

a substrate;

a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information;

a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements;

a plurality of sensors for detecting selections of the input areas; and

one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors.

38. The gaming machine of claim 37, wherein the thickness of the interface display is less than about 3 mm.

39. The gaming machine of claim 37, wherein the thickness of the light emitting layer is less than about 1 micron.

40. The gaming machine of claim 37, wherein the substrate is formed from a flexible material.

41. The gaming machine of claim 40, wherein the flexible material is selected from the group consisting of a plastic film and a metal foil.

42. The gaming machine of claim 37, wherein a portion of the electro-luminescent elements are a matrix of organic light emitting diodes (OLEDs) wherein each OLED forms a pixel in the matrix.

43. The gaming machine of claim 42, wherein the OLED pixels in the matrix are controlled in an active matrix, a passive matrix and combinations thereof.

44. The gaming machine of claim 42, wherein groups of OLED pixels are controlled to display symbols, icons, logo, alpha-numeric text and video frame data.

45. The gaming machine of claim 37, wherein the interface display is operable to vary a number of input areas, a shape of an input area, a size of on an input area, a color of an input area and combinations thereof.

46. The gaming machine of claim 37, wherein gaming information is conveyed by the electro-luminescent elements using a light intensity, a color pattern, a light pattern, a flash rate and combinations thereof.

47. The gaming machine of claim 37, wherein the one or more games is selected from the group consisting of video slot games, mechanical slot games, video black jack games, video poker games, video keno games, video pachinko games, video card games, video games of chance and combinations thereof.

48. The gaming machine of claim 37, wherein a portion of the input areas are used to input gaming information for providing a game service on the gaming machine.

49. The gaming machine of claim 48, wherein the game service is selected from the group consisting of i) viewing account information, ii) performing account transactions iii) receiving operating instructions for the gaming machine, iv) redeeming prizes or comps, v) making entertainment service reservations, vi) participating in casino promotions, vii) selecting entertainment choices for output via video and audio output mechanisms on the gaming machine, viii) playing games and bonus games, ix) performing numerical calculations, x) accessing diagnostic menus, xi) displaying player tracking unit status information, xii) displaying gaming machine status information, xiii) accessing gaming machine metering information and xiv) displaying player status information.

50. The gaming machine of claim 37, wherein a portion of the input areas are for inputting gaming information for playing a game of chance on the gaming machine.

51. The gaming machine of claim 50, wherein the portion of the input areas for inputting gaming information for playing the game of chance are dynamically configurable to display different input selections used by different types of games of chance played on the gaming machine.

52. The gaming machine of claim 37, wherein the plurality of sensors are formed in a sensor layer and are activated by at least one of contact with an object and a proximity of an object.

53. The gaming machine of claim 53, wherein the sensor layer is at least one of a capacitive touch screen, a resistive touch screen, a wave touch screen and combinations thereof.

54. The gaming machine of claim 37, further comprising:

a dynamically configurable electro-luminescent skin for displaying graphical patterns mounted to a portion of the exterior surface of the gaming machine.

55. The gaming machine of claim 37, wherein a first set of graphical patterns is displayed when a first type of game of chance is played on the gaming machine and wherein a second set of graphical patterns is displayed when a second type of game of chance is played on the gaming machine.

56. A gaming machine comprising:

a gaming machine cabinet;

a master gaming controller for controlling one or more games of chance played on the gaming machine located within the interior of the gaming machine;

a main display for displaying the game of chance;

a player tracking unit mounted to the gaming machine cabinet and in communication with the master gaming controller and a player tracking server; said player tracking unit comprising;

a player tracking controller;

one or more player tracking devices;

an interface display for inputting and outputting player tracking information mounted to an exterior surface of the gaming machine cabinet, in communication with the player tracking controller and separate from the main display, said interface display comprising:

a substrate;

a plurality of electro-luminescent elements formed in a light emitting layer on the substrate for outputting gaming information;

a plurality of input areas for inputting gaming information that are illuminated by one or more of the electro-luminescent elements;

a plurality of sensors for detecting selections of the input areas; and

one or more controllers for controlling the plurality of electro-luminescent elements and for controlling the plurality of sensors.

57. The gaming machine of claim 56, wherein the interface display is mounted to an exterior surface of the player tracking unit.

58. The gaming machine of claim 56, wherein the interface display is in communication with the master gaming controller and is operable to allow control by the master gaming controller.

59. The gaming machine of claim 56, wherein the thickness of the interface display is less than about 3 mm.

60. The gaming machine of claim 56, wherein the thickness of the light emitting layer is less than about 1 micron.

61. The gaming machine of claim 56, wherein the substrate is formed from a flexible material.

62. The gaming machine of claim 61, wherein the flexible material is selected from the group consisting of a plastic film and a metal foil.

63. The gaming machine of claim 56, wherein a portion of the electro-luminescent elements are a matrix of organic light emitting diodes (OLEDs) wherein each OLED forms a pixel in the matrix.

64. The gaming machine of claim 63, wherein the OLED pixels in the matrix are controlled in an active matrix, a passive matrix and combinations thereof.

65. The gaming machine of claim 63, wherein groups of OLED pixels are controlled to display symbols, icons, logo, alpha-numeric text and video frame data.

66. The gaming machine of claim 56, wherein the interface display is operable to vary a number of input areas, a shape of an input area, a size of on an input area, a color of an input area and combinations thereof.

67. The gaming machine of claim 56, wherein gaming information is conveyed by the electro-luminescent elements using a light intensity, a color pattern, a light pattern, a flash rate and combinations thereof.

68. The gaming machine of claim 56, wherein the one or more games is selected from the group consisting of video slot games, mechanical slot games, video black jack games, video poker games, video keno games, video pachinko games, video card games, video games of chance and combinations thereof.

69. The gaming machine of claim 56, wherein the plurality of sensors are formed in a sensor layer and are activated by at least one of contact with an object and a proximity of an object.

70. The gaming machine of claim 69, wherein the sensor layer is at least one of a capacitive touch screen, a resistive touch screen, a wave touch screen and combinations thereof.

* * * * *

APPENDIX C

US006856086B2

(12) **United States Patent**
Grace et al.

(10) **Patent No.: US 6,856,086 B2**
(45) **Date of Patent: Feb. 15, 2005**

(54) **HYBRID DISPLAY DEVICE**

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(73) Assignee: **Avery Dennison Corporation**, Pasadena, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 186 days.

(21) Appl. No.: **09/961,846**

(22) Filed: **Sep. 24, 2001**

(65) **Prior Publication Data**

US 2002/0196401 A1 Dec. 26, 2002

Related U.S. Application Data

(60) Provisional application No. 60/300,682, filed on Jun. 25, 2001.

(51) **Int. Cl.**[7] **H01J 19/42; H05B 33/00; G02F 1/13**

(52) **U.S. Cl.** 313/498; 313/501; 313/504; 313/506; 313/244; 313/512; 313/495; 313/292; 428/917; 315/169.3; 315/169.4; 345/207; 349/158; 349/168; 349/175; 349/179; 349/33; 348/790

(58) **Field of Search** 313/244, 312, 313/495, 496, 498, 501, 504, 512, 422, 506, 292; 315/169.3, 169.4; 345/33, 55, 207; 348/790; 349/31–33, 69, 70, 76, 158, 168, 101, 175, 179; 428/917

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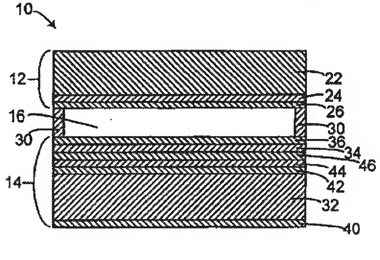
Primary Examiner—Ashok Patel
(74) *Attorney, Agent, or Firm*—Renner, Otto, Boisselle & Sklar, LLP

(57) **ABSTRACT**

A display includes a front panel and a back panel with a light control material in between. One of the panels includes a rigid substrate, for example made of glass or rigid plastic. The other of the panels includes a flexible substrate, for example made of a flexible plastic film. The panel with the flexible substrate may be made by a roll-to-roll process, with various fabrication operations formed while the flexible substrate is still part of a web of material. The panel with the rigid substrate may be separately fabricated, then combined with the other panel on the web through a pick and place operation that accurately locates the front panel relative to the back panel. The display may be any of a variety of displays, such as liquid crystal displays (LCDs), and electroluminescent displays, such as polymer light emitting devices (PLEDs) and organic light emitting devices (OLEDs).

63 Claims, 11 Drawing Sheets



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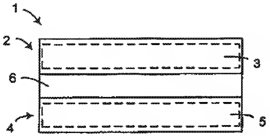

Fig. 1A

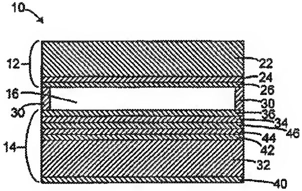

Fig. 1

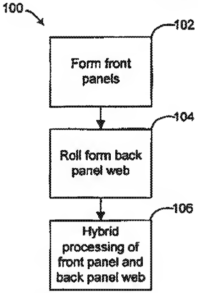

Fig. 2

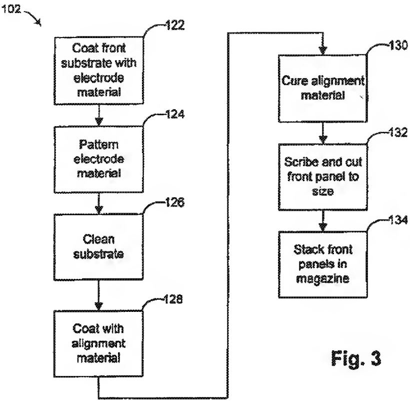
102
122
Coat front substrate with electrode material
124
Pattern electrode material
126
Clean substrate
128
Coat with alignment material
130
Cure alignment material
132
Scribe and cut front panel to size
134
Stack front panels in magazine

Fig. 3

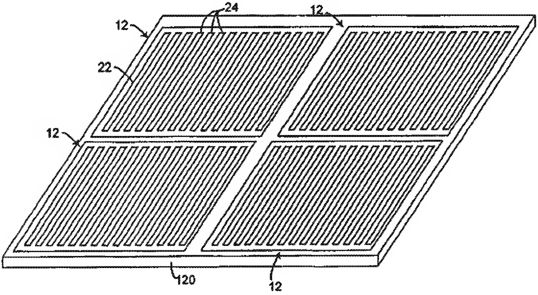
24
12
12
22
12
120
12

Fig. 4

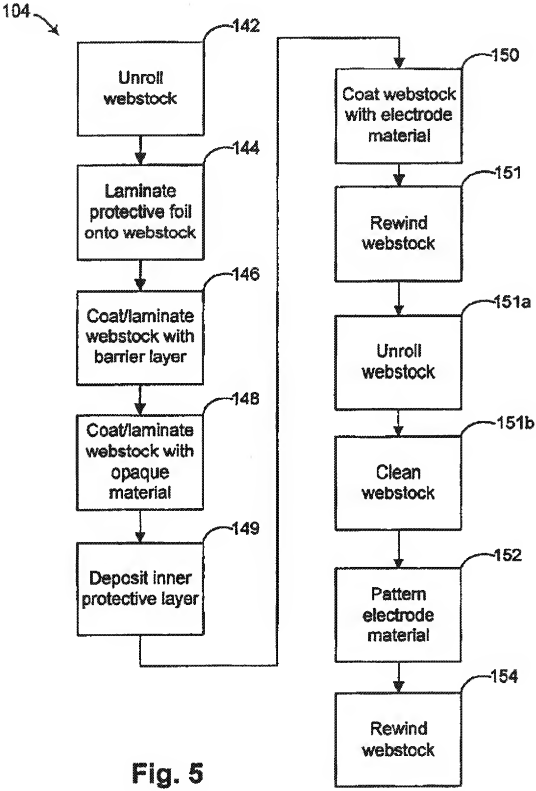
104
142
Unroll webstock
144
Laminate protective foil onto webstock
146
Coat/laminate webstock with barrier layer
148
Coat/laminate webstock with opaque material
149
Deposit inner protective layer
150
Coat webstock with electrode material
151
Rewind webstock
151a
Unroll webstock
151b
Clean webstock
152
Pattern electrode material
154
Rewind webstock

Fig. 5

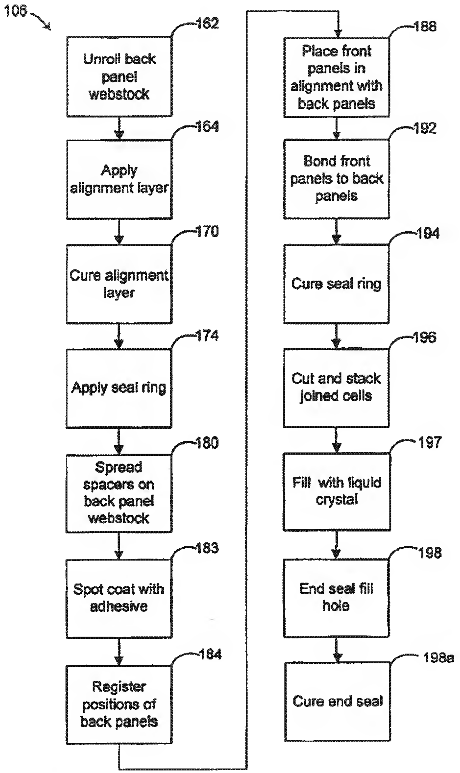
106
Unroll back panel webstock
162
Apply alignment layer
164
Cure alignment layer
170
Apply seal ring
174
Spread spacers on back panel webstock
180
Spot coat with adhesive
183
Register positions of back panels
184
Place front panels in alignment with back panels
188
Bond front panels to back panels
192
Cure seal ring
194
Cut and stack joined cells
196
Fill with liquid crystal
197
End seal fill hole
198
Cure end seal
198a

Fig. 6

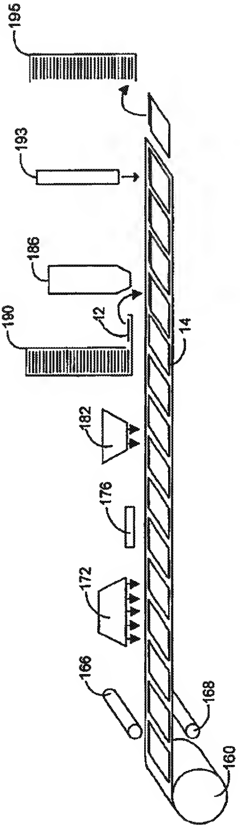

Fig. 7

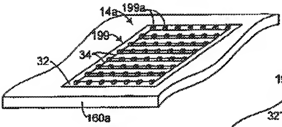

Fig. 8

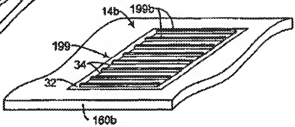

Fig. 9

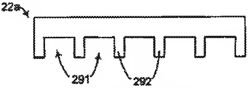

Fig. 10A

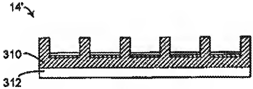

Fig. 11

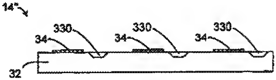

Fig. 12

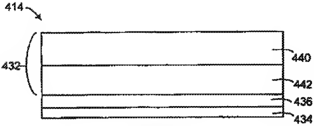

Fig. 13

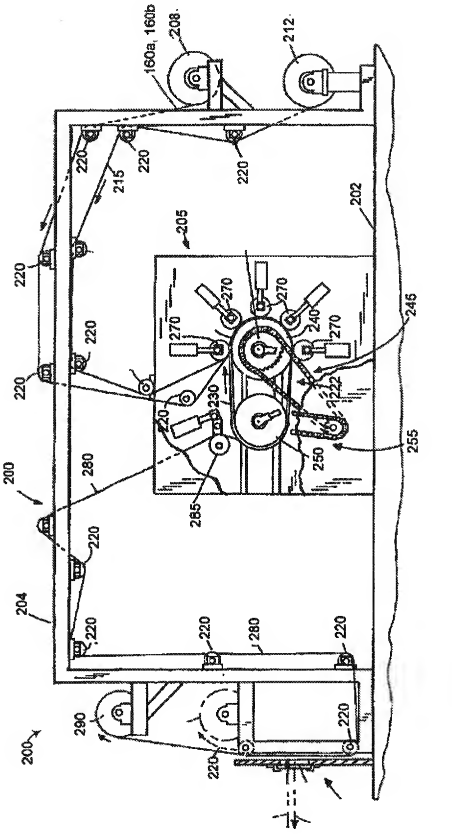
160a, 160b
208
212
220
215
202
205
270
240
245
230
222
250
255
265
280
200
204
290

Fig. 10

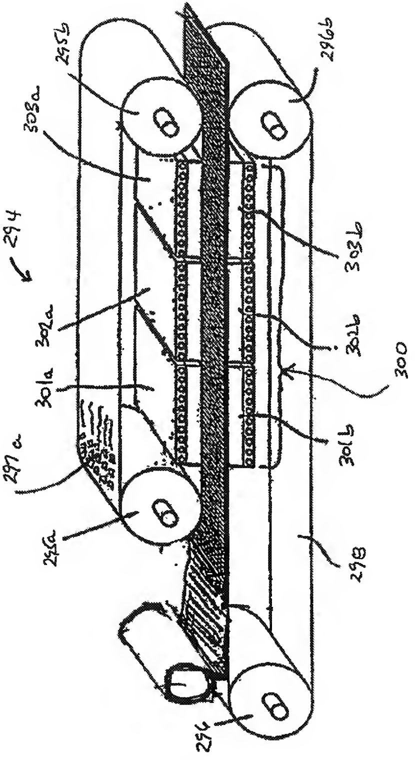
294
295b
296b
303a
303b
302a
302b
301a
301b
300
297a
295a
298
296

FIG. 10B

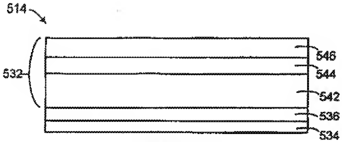

Fig. 14

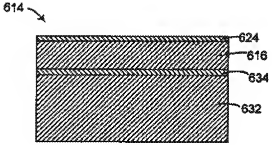

Fig. 15

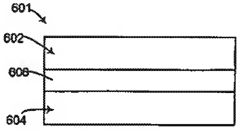

Fig. 14A

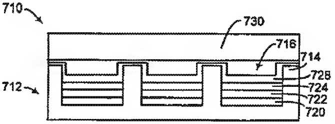

Fig. 16

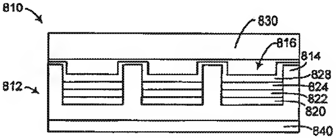

Fig. 17

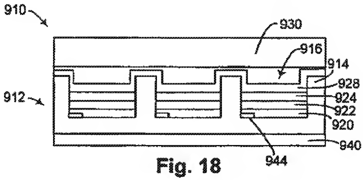

Fig. 18

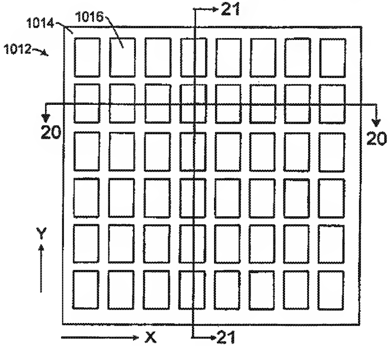

Fig. 19

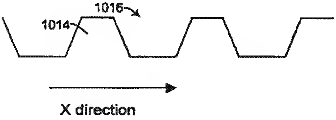

Fig. 20

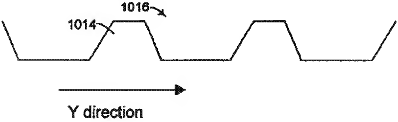

Fig. 21

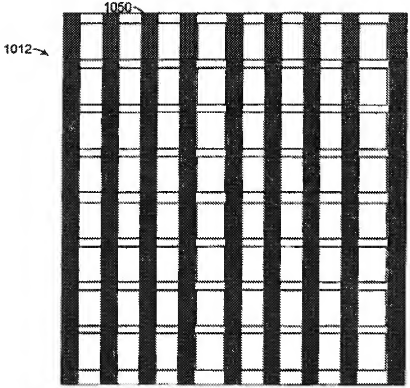

Fig. 22

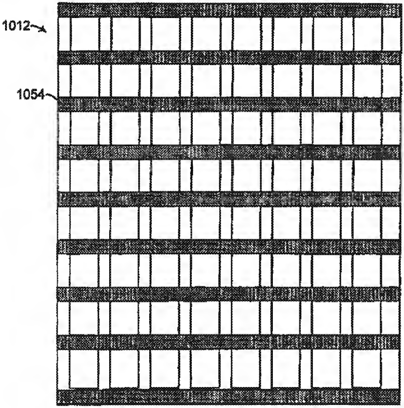

Fig. 23

HYBRID DISPLAY DEVICE

This application claims the benefit of U.S. Provisional Application No. 60/300,682, filed Jun. 25, 2001, which is incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Technical Field of the Invention

The invention relates to optical display devices, and to methods for making the same.

2. Background of the Related Art

Liquid crystal display (LCD) devices are one example of well-known display devices that are useful in a number of applications where light weight, low power and a flat panel display are desired. Typically, these devices comprise a pair of sheet-like, glass substrate elements or "half-cells" overlying one another with liquid crystal material confined between the glass substrates. The substrates are sealed at their periphery with a sealant to form the cell or device. Transparent electrodes are generally applied to the interior surface of the substrates to allow the application of an electric field at various points on the substrates thereby forming addressable pixel areas on the display.

Various types of liquid crystal materials are known in the art and are useful in devices referred to as twisted nematic (TN), super twisted nematic (STN), cholesteric, and ferroelectric display devices.

Other types of display device are electroluminescent displays, such as organic light emitting devices (OLEDs) and polymer light emitting device (PLEDs).

It is desirable to be able to manufacture large area displays of relatively light weight for use in portable devices such as computers, electronic books, personal digital assistants, and the like. Certain organic, polymeric substrates are much lighter than glass while being transparent and are therefore preferred for use over glass in large area, lightweight displays. However, one problem with polymeric substrate displays is the difficulty of properly aligning such substrates, especially if both films are produced using roll-to-roll formation processes. In addition, polymeric substrates often require organic or inorganic coatings with high barrier properties, to prevent ingress of moisture, oxygen, and/or other contaminants into the substrates.

SUMMARY OF THE INVENTION

A display includes a front panel and a back panel with a light control material in between. One of the panels includes a rigid substrate, for example made of glass or rigid plastic. The other of the panels includes a flexible substrate, for example made of a flexible plastic film. The panel with the flexible substrate may be made by a roll-to-roll process, with various fabrication operations formed while the flexible substrate is still part of a web of material. The panel with the rigid substrate may be separately fabricated, then combined with the other panel on the web through a pick and place operation that accurately locates the front panel relative to the back panel. The combined front and back panels may be then separated from the web to form the display. The display may be any of a variety of displays, such as liquid crystal displays (LCDs), and electroluminescent displays, such as polymer light emitting devices (PLEDs) and organic light emitting devices (OLEDs).

According to an aspect of the invention, a display includes a rigid front substrate and a flexible back substrate.

According to another aspect of the invention, a display includes a glass front substrate and a plastic film back substrate.

According to another aspect of the invention, a display includes a rigid plastic front substrate and a flexible plastic film back substrate.

According to still another aspect of the invention, a display device includes a front panel and a back panel with a light control material therebetween, wherein one of the panels has a rigid substrate and the other of the panels has a flexible substrate.

To the accomplishment of the foregoing and related ends, the invention comprises the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the annexed drawings:

FIG. 1A is a schematic cross-sectional view of a display in accordance with the present invention;

FIG. 1 is a schematic cross-sectional view of a liquid crystal display (LCD) device in accordance with the present invention;

FIG. 2 is a high-level flow chart of a method in accordance with the present invention for making the LCD device of FIG. 1;

FIG. 3 is a flow chart of steps of making the front panel of the LCD device of FIG. 1;

FIG. 4 is a perspective view illustrating the sheet processes of FIG. 3;

FIG. 5 is a flow chart of some of the steps of making the back panel of the LCD device of FIG. 1;

FIG. 6 is a flow chart of some of the steps of the hybrid processing of the front and back panels of the device of FIG. 1;

FIG. 7 is a schematic illustration of some of the steps of the hybrid processing of FIG. 6;

FIGS. 8 and 9 are perspective views illustrating roll processes for forming alternate back substrates according to the present invention;

FIG. 10 is an illustration of a machine used in roll processes, for producing protrusions in accordance with the present invention;

FIG. 10A is a schematic cross-sectional view of an alternate front substrate;

FIG. 10B is an illustration of an embossing machine used in producing the front substrate of FIG. 10A;

FIG. 11 is a schematic cross-sectional view of an alternate embodiment back panel for use with the LCD device of FIG. 1;

FIG. 12 is a schematic cross-sectional view of another alternate embodiment back panel for use with the LCD device of FIG. 1;

FIG. 13 is a schematic cross-sectional view of an alternate embodiment back panel in accordance with the present invention;

FIG. 14 is a schematic cross-sectional view of another alternate embodiment back panel in accordance with the present invention;

FIG. 14A is a schematic cross-sectional view of an electroluminescent device in accordance with the present invention;

FIG. 15 is a schematic cross-sectional view of an electroluminescent device back panel in accordance with the present invention;

FIG. 16 is a schematic cross-sectional view of an alternate embodiment electroluminescent device in accordance with the present invention;

FIG. 17 is a schematic cross-sectional view of another alternate embodiment electroluminescent device in accordance with the present invention;

FIG. 18 is a schematic cross-sectional view of yet another alternate embodiment electroluminescent device in accordance with the present invention;

FIG. 19 is a plan view of a microreplicated substrate film in accordance with the present invention;

FIGS. 20 and 21 are cross-sectional views along directions 20—20 and 21—21, respectively, of FIG. 19;

FIG. 22 is a plan view illustrating selective etching of an electrode layer on the substrate film of FIG. 19; and

FIG. 23 is a plan view illustrating selective deposition of an insulator on the substrate film of FIG. 19.

DETAILED DESCRIPTION

Referring to FIG. 1A, a display device 1 includes a front panel 2 having a rigid front substrate 3, and a back panel 4 having a flexible back substrate 5. A light control material 6 is between the front panel 2 and the back panel 4. As used in this patent application, a "light control" material can perform one or more of the following functions: emission of light, and regulation of light from another source by transmission, reflection, and/or refraction. Exemplary types of display devices include LCD devices, for which the light control material is a liquid crystal material, and polymer light emitting devices (PLEDs) and organic light emitting devices (OLEDs), for which the light control material is a light emitting material. An exemplary material for the front substrate is glass, and an exemplary material for the back substrate is a polymer film. The device may be formed by forming the back panels in a series of roll-to-roll operations, and then placing discrete front panels on the back panels through a pick and place operation.

In the description given below, first the substrate of an LCD device is described briefly, in broad terms. Then a process for making the LCD device is described. Following this, the substrate of a PLED device is described in broad terms, and a process of making the PLED device is described with particular attention to operations in which that process differs from the process previously described for LCD devices. Variation on the process and the device are also described throughout.

LCD Devices

Referring to FIG. 1, the general structure of a LCD device 10, an embodiment of the display device 1, is shown. The LCD device 10 includes a front panel 12 and a back panel 14, with a layer of liquid crystal material 16 between the panels 12 and 14. As described in greater detail below, many variations in the configuration the front panel 12 and the back panel 14 are possible.

The front panel 12 may include a front substrate 22, front electrodes 24, and a front alignment or orientation coating or layer 26. A seal ring 30 joins the front panel 12 and the back panel 14, and retains the liquid crystal material 16 between the front panel 12 and the back panel 14. The back panel 14 may include a back substrate 32, back electrodes 34, a back alignment or orientation coating or layer 36, an outer-side protective layer 40, a back barrier layer 42, an opaque layer 44, and an internal protective layer 46.

The front substrate 22 may be a rigid substrate. For example, the front substrate 22 may be a glass substrate. The glass may be a conventionally-available glass, for example having a thickness of approximately 0.2–1 mm. Alternatively, the front substrate 22 may be made of other suitable transparent materials, such as a rigid plastic or a plastic film. The plastic film may have a high glass transition temperature, for example above about 65 degrees C., and may have a transparency greater than 85% at 530 nm.

The back substrate 32 may be a flexible substrate, such as a polymeric film substrate. The back substrate 32 may be made of an optically-transparent thermoplastic polymeric material. Examples of suitable such materials are polycarbonate, polyvinyl chloride, polystyrene, polymethyl methacrylate, polyurethane polyimide, polyester, and cyclic polyolefin polymers. More broadly, the back substrate 32 may be a flexible plastic such as a material selected from the group consisting of polyether sulfone (PES), polyethylene terephthalate (PET), polyethylene naphthalate, polycarbonate, polybutylene terephthalate, polyphenylene sulfide (PPS), polypropylene, aramid, polyamide-imide (PAI), polyimide, aromatic polyimides, polyetherimide, acrylonitrile butadiene styrene, and polyvinyl chloride. Further details regarding substrates and substrate materials may be found in International Publication Nos. WO 00/46854, WO 00/49421, WO 00/49658, WO 00/55915, and WO 00/55916, the entire disclosures of which are herein incorporated by reference in their entireties.

The back substrate 32 may be a transparent polymer film with better than 85% transmission at 530 nm.

The electrodes 24 and 34 may include commonly-known transparent conducting oxides, such as indium tin oxide (ITO). It will be appreciated that other metal oxides may be employed, such as indium oxide, titanium oxide, cadmium oxide, gallium indium oxide, niobium pentoxide, and tin oxide. In addition to a primary oxide, the electrodes may include a secondary metal oxide such as an oxide of cerium, titanium, zirconium, hafnium, and/or tantalum. The possible transparent conductive oxides include ZnO_2, Zn_2SnO_4, Cd_2SnO_4, $Zn_2In_2O_5$, $MgIn_2O_4$, Ga_2O_3—In_2O_3, and TaO_3. The electrodes 24 and 34 may be arranged on the inside surface of the substrates 22 and 32 in either a segmented or X–Y matrix design, as is well known in the art, to form a plurality of picture elements (pixels). The electrodes 24 and 34 may be formed, for example, by low temperature sputtering or direct current sputtering techniques (DC-sputtering or RF-DC sputtering), followed by selective removal of material. Although only a few electrodes are shown, in practice a large number of electrodes are incorporated in the cell and the number will generally increase as the area dimensions of the cell increase. The electrodes 24 and 34 may have leads that are connected to bus leads, which in turn are connected to addressing electronics. The electrodes 24 and 34 may be addressed independently to create an electric field at selected pixels. In some addressing schemes, the electrodes are sequentially and repeatedly scanned at a rapid rate to provide moving images similar to television images. This requires "refreshing" the display at short time intervals to rapidly turn pixels on and off.

In an exemplary embodiment, the electrodes 24 and 34 may each have a width of 200 microns, with a 20 micron gap

between electrodes, thus resulting in a display having pixels that are 200 microns by 200 microns in size, although it will be appreciated that other electrode sizes and gap sizes may be employed. The electrodes may have a sheet resistance of less than about 60 ohms.

The back electrodes 34 alternatively may be opaque electrodes, such as copper or aluminum electrodes. More broadly, the back electrodes may be elemental metal electrodes (opaque or transparent) that contain silver, aluminum, copper, nickel, gold, zinc, cadmium, magnesium, tin, indium, tantalum, titanium, zirconium, cerium, silicon, lead, palladium, or alloys thereof. Metal electrodes on plastic film have the advantage of higher conductivity than ITO electrodes on film.

The alignment coatings 26 and 36 cause a desired orientation of the liquid crystal material 16 at its interface with the panels 12 and 14. This ensures that the liquid crystal rotates light through angles that are complementary to the alignment of the polarizers that may be associated with the cell. The display 10 may include polarizing elements, depending on the type of display (the type of liquid crystal material utilized).

The alignment compositions may include a variety of well-known polymeric materials, for example a polyimide which can be spin coated or printed from solvent, and (if necessary) rubbed with cloth, such as velvet, to provide a useful alignment layer.

The barrier layer 42 prevents moisture and oxygen from being transported through the display. The barrier layer 42 functions to protect layers underneath from environmental damage caused by exposure to oxygen and/or water. In addition, the barrier layer 42 may also function as an adhesion promoter. As the LCD cell gap shrinks, the requirement in barrier performance increases because ingress of fewer water molecules will result in formation of undesirable black spots in the display. The moisture and oxygen barrier may be a conventional suitable material, such as SiO_2. Alternatively, the barrier may be SiO_x, where $1<x<2$. Using SiO_x instead of SiO_2 may provide an additional moisture and oxygen barrier for the display 10, better preventing moisture and oxygen from being transported through the display. The value x for the SiO_x may be controlled, for example, by controlling the oxide ratio in the material used in sputtering the oxide layer, by adding oxygen to an SiO material.

It will be appreciated that the materials for the front substrate 22 and/or the back substrate 32 may be selected to act on their own as a suitable moisture and oxygen barrier. Thus the need for a separate moisture and oxygen barrier may be avoided entirely. For example, a glass front substrate may be sufficiently impermeable to moisture and oxygen to function on its own as a barrier.

Generally speaking, it will be appreciated that the liquid crystal material 16 may include any of a wide variety of suitable liquid crystal materials, such as twisted nematic, cholesteric, and ferroelectric materials.

Twisted nematic liquid crystal devices have a helical or twisted molecular orientation, for example turned by 90 degrees. When an electric field is applied to the liquid crystal material by electrodes incorporated into the device, the molecules re-orient and "unwind" due to the electrical anisotropy of the molecules. This behavior allows the molecules to rotate polarized light when in the twisted state and thereby pass light without rotation when in the untwisted state. When used in combination with polarizers, this ability to rotate polarized light allows the display to act as a light valve, either blocking or passing transmitted or reflected light. When individually addressable electrodes, such as the electrodes 24 and 34, are incorporated into the display, the display device has the ability to display images.

The back panel 14 may be opaque. The opaqueness of the back panel 14 may accomplished in any of a variety of way. For example, the back substrate 32 may be made of an opaque material, such as a suitable opaque polymer material, for example one of the transparent polymer materials discussed above to which a dye or other pigmentation is added. Alternatively, and as illustrated in FIG. 1, the back substrate 32 may include the opaque material layer 44, which may be a polymer which is the same as or different from the transparent polymer of the remainder of the back substrate 32.

Alternatively or in addition, as noted above, the electrode material for the back electrodes 34 itself may be opaque. For example, the electrode material may be aluminum or copper, which is opaque when deposited on the polymer substrate material. The depositing of the electrode material may be by sputtering, for example.

It will be appreciated that a suitable opaqueness may alternatively be achieved by printing an opaque ink between all or a portion of the back substrate 32 and the back electrodes 34.

The opaque substrate and/or electrode material may be used for display devices where light is not transmitted therethrough, but is either reflected by the liquid crystal material or is absorbed by the opaque substrate and/or electrode material. An exemplary suitable liquid crystal material for such a display is a zero field multistable cholesteric liquid crystal mix, such as that described in U.S. Pat. No. 5,889,566, which is incorporated herein by reference. Displays including zero field multistable liquid crystal display (FMLCD) technology have many advantages, such as inherent stability in the display without the need to refresh the display, thus allowing a display that can maintain an image in a no-power mode; excellent sunlight readability; and fast switching operation, for example on the order of 30 milliseconds per frame; and the ability to display various gray scales.

It will be appreciated that alternatively the front panel may be opaque and the back panel transparent, with suitable modifications to the above-described structure.

The front substrate 22 may have an organic coating thereupon to facilitate adhesion of the sealant ring 30. The sealant ring 30 may be made of a conventional suitable sealant material that may be used for containing the liquid crystal material 16 between the front panel 12 and the back panel 14. It will be appreciated that the sealant ring 30 may alternatively be a part of the back panel 14, if desired. The liquid crystal material 16 may be placed between the panels 12 and 14 prior to the joining of the panels, for example by printing the liquid crystal material on either of the panels. Another method is a dispensing method, in which exact amount of liquid crystal is dispensed on to the substrate before joining two panels. Alternatively, and as in the method described below, the liquid crystal material 16 may be placed between the panels 12 and 14 after the joining of the panels 12 and 14, for example by filling the space between the panels through a gap in the sealant ring 30, the gap in the sealant ring subsequently being plugged or otherwise blocked.

In order to allow the preparation of large area displays with uniform spacing and resulting appearance the front panel 12 and/or the back panel 14 may include protrusions

and/or other spacers to maintain desired spacing between the front substrate 22 and the back substrate 32.

The outer-side protective layer 40 serves to protect the back substrate 32 from damage and to give dimensional stability to the film. The protective layer 40 may be a copper or aluminum foil, for example. In embodiments for which the back substrate 32 is transparent and the opaque layer 44 is eliminated, a metal protective layer may also function as a reflective layer. The protective layer also serves as a moisture and oxygen barrier. The protective layer may be a metallic film or a film-foil laminate.

The internal protective layer 46 may be an acrylic hard coat layer. As described in further detail below, laser light such as excimer laser light may be used to pattern the back electrodes 34. The internal protective layer 46 may protect laser light penetrating and damaging functional layers (such as the opaque material layer 44 and the barrier layer 42) between the internal protective layer 46 and the back substrate 32. Acrylic, like other organic polymers, has a relatively low thermal conductivity, thereby minimizing lateral damage in ablation that may accompany the laser ablation to pattern the back electrodes 34. It will be appreciated that other suitable materials, such as other suitable polymers, may alternatively be included in the internal protective layer 46.

Process for Making LCD Devices

Turning now to FIG. 2, a high-level flow chart is shown, providing an overview of a method 100 for fabrication of displays such as the display 10. In step 102, the front panels 12 are formed. The front panels 12 may be formed by sheet handling processes involving a relatively large sheet of material upon which multiple front panels are formed. After formation of the front panel structures on the sheet, the individual front panels may be separated from the sheet.

In step 104 a back panel web is formed by roll-to-roll processing in which the part or all of the structures of the back panels 14 are formed on a web of material, for example on a web of polymer (plastic) film which forms the back substrates 32 of multiple back panels.

Thereafter, in step 106 hybrid processing is performed on the front panels 12 and the back panel web. As explained in greater detail below, further processing is performed on the back panel web to produce the structures of the back panels 14. Then the front panels 12 are placed in proper alignment with and are joined to respective of the back panels 14. The placement of the front panel 12 on the back panel 14 may be accomplished by a pick and place operation. Known suitable mechanical and/or vacuum pick and place devices may be utilized in the pick and place operation.

Referring now to FIGS. 3 and 4, the step 102 of fabricating the front panel 12 includes various sheet processing operations. In the sheet processing operations multiple front panels 12 are fabricated on a single sheet 120 of substrate material. In substep 122, the sheet 120 of substrate material is coated with electrode material, such as ITO. Then in substep 124 the electrode material is patterned, selectively removing some of the electrode material to produce the electrodes 24. The patterning may be accomplished any of a variety of known suitable etching processes, such as wet etching.

After the substrate is cleaned in substep 126, the layer of alignment material 26 is then coated onto the substrate in substep 128. In substep 130, the alignment material 26 is cured or allowed to dry. As noted above, the layer of alignment material 26 may be spin coated or printed, and may be rubbed to produce the desired alignment.

Thereafter, in substep 132, the individual front panels 12 are scribed and separated from each other and from the remainder of the sheet 120. In substep 134 the separate front panels 12 are stacked in a magazine, to be later joined with the web of back panels, such as in a pick and place operation.

It will be appreciated that the substeps 122–134 shown in FIG. 3 and described above are but one method of forming the front panels 12. The sheet processing operations may be performed in a different order, if suitable. In addition, some of the steps described above may be omitted, if desired, and other steps may be substituted or added. For example, the fabrication process may include printing or otherwise depositing the liquid crystal material on the front panel 12. As another example, the fabrication process may include depositing spacers upon the front panel 12 or forming spacers as part of the front panel 12. The spacers function to maintain a desired separation between the front substrate 22 of the front panel 12, and the back substrate 32 of the back panel 14. The spacers may take the form of plastic spheres which are not attached to either of the panels 12 and 14, and which may be sprayed onto the panels. Alternatively, the spacers may be protrusions such as posts, ribs, ridges, or other structures that are formed as part of the front panel 12, for example being attached to the alignment coating layer 26. It will be appreciated that a wide variety of spacers are known in the art, including structures which may be formed after joining of front and back panels, for example by selectively curing a resin material which is mixed with the liquid crystal material.

It will be further appreciated that some or all of substeps of the forming of the front panels 12 may be performed other than as sheet processing operations.

Turning now to FIG. 5, the step 104 of forming of the back panel web begins in substep 142 with unrolling webstock. The webstock acts as a substrate for the back panels 14, and may be a web of plastic film. In substep 144 the webstock is laminated with the protective layer 40, such as a copper foil, on its outer side (the side which will be away from the LCD material when the front panels 12 and the back panels 14 are assembled). The protective layer protects the resulting back panels 14 from damage.

In substep 146 the webstock is coated or laminated with the barrier layer 42 to prevent contaminants such as moisture and oxygen from reaching the liquid crystal material. Then the opaque material 44, such as a layer of black material, is laminated or coated on the webstock in substep 148. The opaque material is used for reflective cells, for example in FMLCD cells in which the liquid crystal material itself reflects light. It will be appreciated that the opaque material may be omitted where non-FMLCD cells are employed, for example in transmissive LCD cells and reflective LCD cells where a metal layer is used as a reflector. In substep 149 the inner protective layer 46 is coated, laminated, or otherwise deposited.

The back electrode material, such as indium tin oxide, is then coated onto the web stock in substep 150. As noted above, the electrode material may be a copper or aluminum that is deposited, such as by sputter coating, or is printed, onto the webstock. After coating, the webstock is rewound in substep 151, and is sent to a separate processing station for electrode patterning.

The further processing begins in substep 151 a with unwinding of the webstock. Then in substep 151*b* the webstock is cleaned. In substep 152, the electrode material is patterned to form the electrodes. The patterning may include conventional processes, such as wet etching. Alter-

natively or in addition, the patterning may include ablation of the electrode material to remove the electrode material between electrodes. The ablation may include removal of the electrode material through use of an excimer laser. For example, an XeCl excimer laser with a wavelength of 308 nm or a KRF excimer laser with a wavelength of 248 nm may be used to ablate the electrode material. The laser may provide a range of energy per pulse of 50–1000 mJ/cm^2, spectrally narrowed laser wavelengths with the difference between longer and shorter wavelengths being about 0.003 nm or less, large beam dimensions (e.g., 7 mm by 7 mm (about 50 mm^2)). Further details of excimer laser ablation may be found in U.S. application Ser. No. 09/783,105, filed Feb. 14, 2001, titled "Multilayered Electrode/Substrate Structures and Display Devices Incorporating the Same," and U.S. application Ser. No. 09/783,122, filed Feb. 14, 2001, titled "Multilayer Electrode/Substrate Structures and Liquid Crystal Devices Incorporating the Same," both of which are herein incorporated by reference in their entireties.

Finally, in substep 154 the webstock is rewound to await further processing in the hybrid processing step 106.

The substeps 142–154 may be performed in one or more roll-to-roll operations. The substeps 142–154 are merely one example of substeps employed in forming the back webstock, and it will appreciated that other steps may be added, and/or that some of the steps described above may be suitably altered and/or omitted, if desired.

FIG. 6 shows a flow chart of substeps in the hybrid processing step 106. FIG. 7 schematically illustrates roll processing involving some of the substeps. In the roll processing of the hybrid processing step 106, a back webstock 160 may be indexed at some or all of the processing stations in the roll processing. In substep 162 a roll of the back webstock 160 is unwound. The back webstock 160 is webstock such as that produced in the step 104 described above with respect to FIG. 5.

In substep 164 the alignment layer 36 is applied to the webstock 160. The alignment layer 36 may be a polyimide alignment layer printed on the webstock 160 by use of a flexo press, which is schematically represented by press rollers 166 and 168 in FIG. 7. Alternatively, the alignment layer material 36 may be deposited by sputtering, or by other suitable methods, such as physical vapor deposition (PVD) or spin coating. The alignment layer 36 is cured in substep 170, for example by subjecting the webstock to heating from a heater 172. If desired, the alignment layer 36 may be rubbed or otherwise treated to impart a directional alignment to the layer.

Thereafter the seal ring 30 is applied in substep 174. The seal ring 30 may be applied by printing of the seal ring at appropriate locations on the webstock 160, by use of a printing device 176. In substep 180, spacers are spread on the webstock 160, such as by spraying the spacers on the webstock 160 using a sprayer 182. In substep 183 the alignment material 26 is spot-coated with adhesive material, such as a UV-curable adhesive material. The adhesive material may patterned to be located at the perimeter of the front panels 12 so that the panels may be later anchored to a web of back panels.

In substep 184 the position of the back panel 14 on the webstock 160 is registered, for example using a CCD camera 186 to detect a registration or alignment mark on or near the back panel 14. Then in substep 188 the front panel 12 is removed from a magazine 190 and placed on the back panel 14 in a pick and place operation. It will be appreciated that the magazine 190 may be the same magazine into which the front panels 12 were loaded in substep 134 of step 102, as described above. The front panels 12 may be advanced to the front of the magazine 190 by a spring, and may be lightly retained for pick off by springy or mechanically retracting retainer fingers.

The pick and place operation may be performed by a pick and place device, which may include mechanical and/or vacuum grips to grip the front panel 12 while moving it into the desired location in alignment with the back panel 14. It will be appreciated that a wide variety of suitable pick and place devices are well known. Examples of such devices are the devices disclosed in U.S. Pat. Nos. 6,145,901, and 5,564,888, both of which are incorporated herein by reference, as well as the prior art devices that are discussed in those patents. Alternatively, rotary placers may be utilized to place the front panel 12 upon the back panel 14. An example of such a device is disclosed in U.S. Pat. No. 5,153,983, the disclosure of which is incorporated herein by reference.

The registration of the back panel 14 may be coordinated with placement of the front panel 12 on the back panel 14. For example, the CCD camera 186 and the pick and place device may be operatively coupled so as to insure alignment of the front panel 12 relative to the back panel 14 during and/or after the placement of the front panel onto the back panel. It will be appreciated that use of the pick and place device allows greater accuracy in the placement of the front panel 12 relative to the back panel 14, when compared to joining of front and back panels roll-to-roll processes involving combining respective front and back panel rolls. Devices produced by combining front and back panels from respective rolls may be prone to errors in alignment, due to the variations in dimension which may occur during fabrication of the front and back panels, variations in dimensions due to heating, stretching, and other processes involved in roll-to-roll fabrication.

The alignment during and after placement of the front panel 12 on the back panel 14 may improve electrode registration between the front electrodes 24 of the front panel 12 and the back electrodes 34 of the back panel 14. The electrodes of the panels may be registered to within 5 microns, and may even be registered to within 1 micron.

It will be appreciated that the front panels 12 must be sufficiently rigid so as to maintain sufficient dimensional stability and stiffness throughout the pick and place and registration processes. If the front panels 12 are too limp, they may flutter during the pick and place operation, interfering with proper position of the front panel 12 relative to the back panel 14. As an example, a suitable Gurley stiffness of the front panels in the machine direction may be about 40 mg or greater. Further information regarding acceptable stiffness for pick and place operations may be found in U.S. Pat. No. 6,004,682, the specification of which is incorporated herein by reference.

Thereafter, in substep 192, the front panel 12 is bonded to the back panel 14. The bonding may be accomplished by using a UV light source 193 to spot cure the adhesive applied to the front panel 12 in substep 183 of step 106, described above. The spot coating provides a way of quickly anchoring the front panel 12 and the back panel 14 together, to maintain the desired relative alignment of the front panel 12 and the back panel 14 during further processing steps.

Thereafter, the sealant rings 30 of the combined front and back panels may be cured in substep 194, such as by heating or by exposure to suitable radiation. Then, the combined

front and back panels are cut and stacked in substep 196, and are loaded into a magazine 195. The space between the front panel 12 and the back panel 14 is filled with liquid crystal material in substep 197. Then the gap in the sealant ring 30 may be filled in substep 198 and cured in substep 198a. Further steps, such as singulating the displays 10 and testing the displays, may then be performed.

The fabrications steps and substeps described above are merely one example of the fabrication of a display, and it will be appreciated that the above-described method may be suitably modified by adding, removing, or modifying steps or substeps. For example, the display material alternatively may be deposited by printing, such as by ink jet printing or printing using a letterpress.

Formation of Protrusions and Recesses on Panels

Turning now to FIGS. 8 and 9, back panels 14a and 14b, specific embodiments of the back panel 14, are shown upon respective back panel webstocks 160a and 160b. The back panels 14a and 14b include spacers for supporting the substrates in a spaced-apart relationship. As illustrated in FIGS. 8 and 9, the spacers may include protrusions 199 such as posts 199a and/or ribs 199b, in any of a variety of suitable shapes and/or configurations. For example, the spacers may have a tapered cross section, have a broader base and a narrower top part. Such a tapered shape may facilitate removal of electrode material from tops and sides of walls of the posts/ribs, which may help in avoiding short circuiting in the display 10.

The posts 199a may be located such that they do not contact either the back electrodes 34 or the front electrodes 24. The posts 199a and the ribs 199b may be used in conjunction with unattached spacers, such as the spherical plastic spacers described above.

The posts 199a and/or the ribs 199b may be formed prior to the coating with electrode material performed in substep 150 in the fabrication method described above. It will be appreciated that suitable modifications may be made in the above-described fabrication method to account for the presence of the posts 199a and/or the ribs 199b.

The posts 199a and/or the ribs 199b may be physically and chemically integral to the back substrate 32, and may be formed by a microreplication process. One technique of microreplicating arrays with very small surfaces requiring a high degree of accuracy is found in the use of continuous embossing to form cube corner sheeting. A detailed description of equipment and processes to provide optical quality sheeting are disclosed in U.S. Pat. Nos. 4,486,363 and 4,601,861. Tools and a method of making a tool used in those techniques are disclosed in U.S. Pat. Nos. 4,478,769; 4,460,449; and 5,156,863. The disclosures of all the above patents are incorporated herein by reference.

A machine 200 for producing a substrate such as that described above is shown in elevation in FIG. 10, suitably mounted on a floor 202. The machine 200 includes a frame 204, centrally located within which is an embossing means 205.

A supply reel 208 of unprocessed thermoplastic web 160a, 160b is mounted on the right-hand side of the frame 204; so is a supply reel 212 of flexible plastic film 215. An example of a suitable flexible plastic film 215 is a PET film available from DuPont, which is heat stabilized and has a glass transition temperature of 78 degrees C. and a use temperature of up to 120 degrees C. The flat web 160a, 160b and the film 215 are fed from the reels 208 and 212, respectively, to the embossing means 205, over guide rollers 220, in the direction of the arrows.

The embossing means 205 includes an embossing tool 222 in the form of an endless metal belt 230 which may be about 0.020 inches (0.051 cm) in thickness. The width and circumference of the belt 230 will depend in part upon the width or material to be embossed and the desired embossing speed and the thickness of the belt 230. The belt 230 is mounted on and carried by a heating roller 240 and a cooling roller 250 having parallel axes. The rollers 240 and 250 are driven by chains 245 and 255, respectively, to advance belt 230 at a predetermined linear speed in the direction of the arrow. The belt 230 is provided on its outer surface with a continuous female embossing pattern 260 that matches the general size and shape of the particular protrusions (posts 199a and/or ribs 199b) to be formed in the web 160a, 160b.

Evenly spaced sequentially around the belt, for about 180° around the heating roller 240, are at least three, and as shown five, of pressure rollers 270 of a resilient material, preferably silicone rubber, with a durometer hardness ranging from Shore A 20 to 90, but preferably, from Shore A 60 to 90.

While rollers 240 and 250 may be the same size, in the machine 200 as constructed, the diameter of heating roller 240 is about 10.5 inches (26.7 cm) and the diameter of cooling roller 250 is about 9 inches (22.9 cm). The diameter of each pressure roller 270 is about 6 inches (15.2 cm).

It may be desirable to maintain additional pressure about the tool and substrate during cooling, in which case the cooling roller 250 could be larger in diameter than the heating roller, and a plurality of additional pressure rollers, (not shown) also could be positioned about the cooling roller.

Either or both heating roller 240 or cooling roller 250, has axial inlet and outlet passages (not shown) joined by an internal spiral tube (not shown) for the circulation therethrough of hot oil (in the case of heating roller 240) or other material (in the case of cooling roller 250) supplied through appropriate lines (not shown).

The web 160a, 160b and the film 215, as stated, are fed to the embossing means 205, where they are superimposed to form a laminate 280 which is introduced between the belt 230 and the leading roller of the pressure rollers 270, with the web 160a, 160b between the film 215 and the belt 230. From thence, the laminate 280 is moved with the belt 230 to pass under the remaining pressure rollers 270 and around the heating roller 240 and from thence along belt 230 around a substantial portion of cooling roller 250. Thus, one face of web 160a, 160b directly confronts and engages embossing pattern 260 and one face of the film 215 directly confronts and engages pressure rollers 270.

The film 215 provides several functions during this operation. First, it serves to maintain the web 160a, 160b under pressure against the belt 230 while traveling around the heating and cooling rollers 240 and 250 and while traversing the distance between them, thus assuring conformity of the web 160a, 160b with the precision pattern 260 of the tool during the change in temperature gradient as the web (now embossed substrate) drops below the glass transition temperature of the material. Second, the film 215 maintains what will be the outer surface of substrate in a flat and highly finished surface for other processing, if desired. Finally, the film 215 acts as a carrier for the web 160a, 160b in its weak "molten" state and prevents the web from adhering to the pressure rollers 270 as the web is heated above the glass transition temperature.

The embossing means 205 finally includes a stripper roller 285, around which laminate 280 is passed to remove

the same from the belt **230**, shortly before the belt **230** itself leaves cooling roller **250** on its return path to the heating roller **240**.

The laminate **280** is then fed from stripper roller **285** over further guiding rollers **220**, eventually emerging from frame **204** at the lower left hand corner thereof. Laminate **280** is then wound onto a storage winder **290** mounted on the outside of frame **204** at the left hand end thereof and near the top thereof. On its way from the lower left hand corner of frame **204** to winder **290**, additional guiding rollers guide the laminate **280**.

The heating roller **240** is internally heated (as aforesaid) so that as belt **230** passes thereover through the heating station, the temperature of the embossing pattern **260** at that portion of the tool is raised sufficiently so that web **160***a*, **160***b* is heated to a temperature above its glass transition temperature, but not sufficiently high as to exceed the glass transition temperature of the film **215**.

The cooling roller **250** is internally "fueled" (as aforesaid) so that as belt **230** passes thereover through the cooling station, the temperature of the portion of the tool embossing pattern **260** is lowered sufficiently so that web **160***a*, **160***b* is cooled to a temperature below its glass transition temperature, and thus becomes completely solid prior to the time laminate **280** is stripped from tool **230**.

It has been found that the laminate **280** can be processed through the embossing means **205** at the rate of about 3 to 4 feet per minute, with satisfactory results in terms of the accuracy and dimensional stability and other pertinent properties of the finished substrate.

It will further understood that temperatures of the heating roller and cooling rollers may need to be adjusted within certain ranges depending upon the web material selected. Certain materials have higher glass transition temperature T_G than others. Others may require cooling at a higher temperature then normal and for a longer time period. Preheating or additional heating at the entrance of the nips may be accomplished by a laser, by flameless burner, or by another device, and/or by adjusting the temperature of the heating roller to run at higher preselected temperature. Similar adjustments may be made at the cooling level.

A preferred material for the embossing tool disclosed herein is nickel. The very thin tool (about 0.010 inches (0.025 cm) to about 0.030 inches (0.076 cm)) permits the rapid heating and cooling of the tool **230**, and the web **160***a*, **160***b*, through the required temperatures gradients while the pressure rolls and the carrier film apply pressure. The result is the continuous production of a precision pattern where flatness and angular accuracy are important while permitting formation of sharp corners with minimal distortion of other surfaces, whereby the finished substrate provides an array of protrusions (such as posts **199***a* and/or ribs **199***b*) formed with high accuracy.

The embossing means described herein, with suitable modifications of the tooling, substrate materials and process conditions, may be used to produce any one of the various substrate configurations disclosed herein. For example, in addition to the LCD spacer protrusions of **199***a* and **199***b*, the embossing means may be used to produce additional formations, including the recesses of the substrate of FIG. **12** and the ridges and wells of the substrate film for PLEDs of FIG. **16**.

An alternative method of forming the protrusions **199***a* and/or **199***b* of FIGS. **8** and **9** is by printing UV-curable resins on a substrate, and then curing the resins to form the protrusions. An example of a suitable material is a black matrix material commonly used in making color filters, such as the OPTIMER CR Series Pigment Dispersed Color Resist available from JSR Corporation of Japan. Another example of UV-curable resins is UV-curable epoxy acrylates. The printing may be accomplished by ink jet printing or screen printing, for example. Further information regarding ink jet printing and screen printing may be found in U.S. Pat. No. 5,889,084, and U.S. Pat. No. 5,891,520, the disclosures of which are incorporated herein by reference. Other methods of forming microstructures with UV-curable resins may be found in International Publication No. WO 99/08151.

A further method of forming a substrate element includes forming protrusions on a major surface of a substrate by a photolithography process. The photoresist for the photolithography process may be a black matrix material of the type commonly used for producing color filters. A preferred material of this type is CSP series photo-sensitive rib materials by Fuji Film Olin Co., Ltd (Japan).

It will be appreciated that a structure or arrangement of protrusions and recesses may also be formed on a rigid substrate, an example being the front substrate **22***a* shown in FIG. **10**A. The front substrate **22***a* has recesses **291** surrounded or bordered by protrusions **292**. The arrangement of the recesses **291** and protrusions **292** on the rigid front substrate **22***a* may include any of a variety of suitable geometries of recesses and protrusions.

The arrangement of the recesses **291** and the protrusions **292** may be formed by any of a variety of suitable methods. For example, the above-described methods involving printing and curing UV-curable resins, and photolithography, may be utilized. As another alternative, a suitable embossing process may be used to form the arrangement of recesses and protrusions. A press **294** for carrying out an embossing process on rigid substrates is shown in FIG. **10**B, and its operation is described briefly below. Further details regarding embossing of rigid materials may be found in commonly-assigned, co-pending U.S. patent application Ser. No. 09/596,240, entitled "A Process for Precise Embossing", filed Jun. 6, 2000, and in International Application PCT/US01/18655, filed Jun. 8, 2001. Both of these applications are incorporated herein by reference in their entireties.

Continuous presses, of which the press **294** of FIG. **10**B is an example, include double band presses which have continuous flat beds with two endless bands or belts, usually steel, running above and below the product and around pairs of upper and lower drums or rollers. These form a pressure or reaction zone between the two belts and advantageously apply pressure to a product when it is flat rather than when it is in a curved form. The double band press also allows pressure and temperature to vary over a wide range. Dwell time or time under pressure is easily controlled by varying the production speed or rate, and capacity may be changed by varying the speed, length, and/or width of the press.

In use, the product is "grabbed" by the two belts and drawn into the press at a constant speed. At the same time, the product, when in a relatively long flat plane, is exposed to pressure in a direction normal to the product. Of course, friction is substantial on the product, but this may be overcome by one of three systems. One system is the gliding press, where pressure-heating plates are covered with low-friction material such as polytetrafluoroethylene and lubricating oil. Another is the roller bed press, where rollers are placed between the stationary and moving parts of the press. The rollers are either mounted in a fixed position on the pressure plates or incorporated in chains or roller "carpets" moving inside the belts in the same direction but at half

speed. The roller press is sometimes associated with the term "isochoric." This is because the press provides pressure by maintaining a constant distance between the two belts where the product is located. Typical isochoric presses operate to more than 700 psi.

A third system is the fluid or air cushion press, which uses a fluid cushion of oil or air to reduce friction. The fluid cushion press is sometimes associated with the term "isobaric" and these presses operate to about 1000 psi. Pressure on the product is maintained directly by the oil or the air. Air advantageously provides a uniform pressure distribution over the entire width and length of the press.

In double band presses, heat is transferred to thin products from the heated rollers or drums via the steel belts. With thicker products, heat is transferred from heated pressure plates to the belts and then to the product. In gliding presses, heat is also transferred by heating the gliding oil itself. In roller bed presses, the rollers come into direct contact with the pressure-heating plates and the steel belts. In air cushion presses, heat flows from the drums to the belts to the product, and, by creating turbulence in the air cushion itself, heat transfer is accomplished relatively efficiently. Also, heat transfer increases with rising pressure.

Another advantage of the double band press is that the product may be heated first and then cooled, with both events occurring while the product is maintained under pressure. Heating and cooling plates may be separately located one after the other in line. The belts are cooled in the second part of the press and these cooled belts transfer heat energy from the product to the cooling system fairly efficiently.

Continuous press machines fitting the general description provided hereinabove are sold by Hymmen GmbH of Bielefeld, Germany (U.S. office: Hymmen International, Inc. of Duluth, Ga.) as models ISR and HPL. These are double belt presses and also appear under such trademarks as ISOPRESS and ISOROLL. To applicants' knowledge, such presses heretofore have not generally been used to emboss precise recesses, especially with polymeric materials.

Using the press in forming an arrangement of protrusions and recesses on a rigid substrate, such as a thermoplastic substrate, involves the following steps: providing a continuous press with an upper set of rollers, a lower set of rollers, an upper belt disposed about the upper set of rollers, a lower belt disposed about the lower set of rollers, a heating station, a cooling station, and pressure producing elements; passing an amorphous thermoplastic material through the press; heating the material to about 490° F. (255° C.); applying pressure of at least about 250 psi (17 bars) to the material; cooling the material to near its T_g and, if desired, maintaining pressure on the material while the material is cooled.

Making reference to FIG. 10B, details of the press **294** are now described. The press **294** includes a pair of upper rollers ***295a***, ***295b*** and a pair of lower rollers ***296a***, ***296b***. The upper roller ***295a*** and the lower roller ***296a*** may be oil heated. Typically the rollers are about 31.5 inches in diameter and extend for about 27.5 inches (70 cm). Around each pair of rollers is a steel (or nickel) belt **297**, **298**. An upper patterned belt **297** is mounted around the upper rollers ***295a***, ***295b*** and a lower plain belt **298** is mounted around the lower rollers ***296a***, ***296b***. Only a portion of the pattern is illustrated, but it is understood that it will contain an array of male elements designed to provide the necessary size and shape of the receptor recesses **291**. These belts may be generally similar to those continuous belts described above in conjunction with the continuous roll embossing process, for machine **200** (FIG. 10).

Heat and pressure are applied in a portion of the press referred to as the reaction zone **300**. Within the reaction zone are means for applying pressure and heat, such as three upper matched pressure sections ***301a***, ***302a***, ***303a*** and three lower matched pressure sections ***301b***, ***302b***, ***303b***. Each section is about 39 inches (100 cm) long and the width depends on the width of roll desired, one example being 27.5 inches (70 cm). Heat and pressure may be applied in other ways that are well known by those skilled in the art. Also, it is understood that the dimensions set forth are for existing or experimental continuous presses, such as those manufactured by Hymmen; these dimensions may be changed if desired.

The lower belt **298** will be smooth if only one side of a product is to be embossed. It is to be understood that the pressure sections may be heated or cooled. Thus, for example, the first two upstream pressure sections, upper sections ***301a***, ***302a*** and the first two lower sections ***301b***, ***302b*** may be heated whereas the last sections ***303a*** and ***303b*** may be cooled or maintained at a relatively constant but lower temperature than the heated sections.

Thermoplastic materials such as polysulfone, polyarylate, high T_g polycarbonate, polyetherimide, and copolymers may be used in the press **294** (or the embossing machine **200**). With such material, the pressure range is approximately 180 to 1430 psi and the temperature range is approximately 485° F. to 580° F. (250° C. to 340° C.). Material thicknesses of 75 μm to 250 μm may be embossed to provide the desired receptor recesses.

With the dimensions and reaction zones stated above, the process rate may move at about 21 to 32 feet per minute.

As discussed above, the embossing machine **200** shown in FIG. **10** would generally be suitable for use with relatively flexible materials, while the press **294** shown in FIG. **10B** would generally be suitable for use with relatively rigid materials. The choice as to which type of microreplicating machine to employ may depend on the thickness and elasticity modulus of the material to be microreplicated. For example, polycarbonate has a modulus of elasticity of 108 Pascals, as determined according to ASTM D882. Films of polycarbonate less than about 15 mils thick would preferably be run through a belt embosser, while films of polycarbonate greater than about 30 mils thick would preferably be run through a flat bed embosser. For materials with very low elasticity modulus, such as a rubbery foam, the upper limit of thickness for a belt embosser would be higher.

Alternative Back Panels

FIGS. **11–14** illustrate further alternate embodiments of the back panel **14**. Turning initially to FIG. **11**, a back panel **14"** includes an opaque material layer **310** on and/or joined to a transparent material **312**. The opaque material layer **310** and the transparent material **312** may be a part of the back substrate. Alternatively, the opaque material layer may be a coating or other material layer which is on the transparent material, but which is not a part of the back substrate.

The opaque material layer **310** may be a polymer material with a pigment or dye added, as described above. It will be appreciated that the opaque material layer **310** may be placed on top of the transparent material **312**, forming part of the protrusions **302**. Alternatively, the opaque material layer **310** may be underneath or within the transparent material. The opaque material may be of the same polymer type as the transparent material, or may be a different type of polymer. The opaque material layer may be joined to the transparent material by a variety of suitable, well-known

methods. For instance, the opaque material layer 310 may be bonded with the transparent material 312 in a roll operation using the machine 200 shown in FIG. 10.

Alternatively, the opaque material layer 310 may be a metallic layer deposited on the transparent material 312 by sputtering or another suitable deposition method. As another alternative, the opaque material layer 310 may be an opaque ink layer.

Referring to FIG. 12, a back panel 14", another alternate embodiment of the back panel 14, has driving electronics microstructure elements 330 embedded in the back substrate 32. The microstructure elements 330 are small electronic elements which may contain rudimentary driving logic, and which may be placed in corresponding recesses in the substrate 32 by such processes as fluidic self assembly. Further details regarding microstructure elements may be found in the above-mentioned International Publication Nos. WO 00/46854, WO 00/49421, WO 00/49658, WO 00/55915, and WO 00/55916, as well as in U.S. Provisional Application No. 60/252,247, the entire disclosure of which is herein incorporated by reference.

The back electrodes 34 of the back panel 14" are metal electrodes, such as copper or aluminum electrodes. Use of metal electrodes may allow for easier connection between the electrodes 34 and the microstructure elements 330, when compared to conventional connections between ITO electrodes and microstructure elements. Specifically, electrochemical problems of interconnections between ITO electrodes and Al conductors of the microstructure elements may be avoided.

Turning now to FIG. 13, a back panel 414 includes a substrate 432 and back electrodes 434, with a solvent-resistant or primer layer 436 therebetween. The substrate 432 includes a metal foil layer 440 laminated on a substrate film 442.

The metal foil layer 440 may include an aluminum foil, a copper foil, or a stainless steel foil. The metal foil may be from 25 to 75 microns thick. The metal foil 440 functions both as a reflective layer and a barrier layer.

The substrate film 442 may include a polycarbonate film, a PET film, or a PES film. The substrate film 442 may have a thickness from 50 to 200 microns. The polycarbonate film may have a glass transition temperature from 120 to 220 degrees C. Suitable polycarbonate films include HA 120 and HT 200 films available from Teijin Limited, of Osaka, Japan. A suitable PET film is a PET film available from DuPont, which is heat stabilized and has a glass transition temperature of 78 degrees C. and a use temperature of up to 120 degrees C. It will be appreciated that other substrate film materials may be employed, such as those discussed above.

The solvent-resistant or primer layer may include an acrylic coating with a thickness of about 1 to 5 microns. The solvent-resistant material protects the underlying material from solvents used in later fabrication/processing operations, such as in depositing/coating an alignment material, or in wet etching to pattern the electrodes 434.

The back electrodes 434 may include ITO, a metal such as silver or aluminum, or a metal alloy such as a silver alloy. The ITO may have a surface resistance from 30 to 60 ohm/square. The silver or silver alloy may have a surface resistance from 5 to 30 ohm/square. The aluminum electrodes may have a surface resistance from 1 to 30 ohm/square.

FIG. 14 shows a back panel 514 that includes a back substrate 532 and back electrodes 534, with a primer layer 536 between the back substrate and the back electrodes.

The back substrate 532 includes a substrate film layer 542, coated on its back side with a barrier layer 544 and a protective opaque layer 546. Alternatively, the barrier layer 544 may be on the inside of the substrate film layer 542. The back substrate 532 may be a laminate. The substrate film layer 542 may be similar to the substrate film layer 442 shown in FIG. 13 and discussed above. The barrier layer 544 and the opaque layer 546 may include materials discussed above with regard to other embodiments. In addition, alternatively the barrier layer 544 may be a multilayer coating, such as a coating of alternating polymer and SiO_x layers.

The primer layer 536 may include an acrylic coating 2 to 5 microns thick.

The electrodes 534 may be similar to the electrodes 434 shown in FIG. 13 and discussed above.

It will be appreciated that the back panels 414 and 514 may be modified to include microreplicated spacers (such as shown in FIGS. 8, 9, and 11, and described above), microreplicated receptor holes for microstructure elements (such as shown in FIG. 12), and/or via holes in the back substrates 424 and/or 524 to allow interconnection of driver electronics for selectively actuating (providing power to) individual of the back electrodes 434 and 534.

The back panels 414 and 514 may be utilized with suitable front panels. Front panels for utilization with the back panels 414 and 514 may include glass panels, for example 0.2 to 1 mm thick, with patterned electrodes, for example ITO electrodes having a surface resistance from 1 to 60 ohm/square. Alternatively, front panels for utilization with the back panels 414 and 514 may include rigid plastic panels with light transmission greater than 85% in the visible range, for example 0.2 to 2.5 mm thick polycarbonate or polymethylacrylate, with patterned electrodes, such as ITO electrodes having a surface resistance from 1 to 60 ohm/square. The resulting combination of the back panels 414 or 514 with suitable front panels may be utilized in liquid crystal displays.

Electroluminescent Displays

Referring now to FIG. 14A, an electroluminescent display device 601 is shown. The electroluminescent display device 601 is a specific embodiment of the display device shown in FIG. 1. The electroluminescent display device 601 includes a front substrate 602 and a back substrate 604, with a light emitting structure 606 therebetween. The light emitting structure 606 may include multiple layers, such as an anode, a hole transport layer, an emissive layer, and a cathode. The light emitting structure may also include other layers, such as a hole injection layer and/or an electron transport layer. Some of these layers may be suitably combined. For example, emissive material may be embedded in the electron transport layer. The layers between the anode and the cathode are generally referred to herein as "light emitting material."

FIGS. 15–19 show various embodiments of the electroluminescent display device 601 and/or parts thereof. Referring initially to FIG. 15, a back panel 614 for an electroluminescent display device includes an emitter and other layers (indicated generally as 616 and also referred to as a light emitting material) that can be made to electroluminesce by applying a voltage across the material by means of electrodes 624 and 634. As noted above, the layers 616 may include a hole transport material and the emitter. The back panel 614 may be part of an organic light emitting device (OLED) or alternatively may be a part of a polymer light emitting device (PLED). When a sufficiently large voltage is

applied across the layers 616 by the electrodes 624 and 634, electrons are ejected from one of the electrodes (the cathode) and holes are emitted from the other of the electrodes (the anode). The electron-hole combinations are unstable, and combine in the emitter to release energy in the form of light.

The layers 616 may include any of a variety of suitable materials, such as semiconductor materials; organic compounds such as conjugated organics or conjugated polymers that have many of the characteristics of semiconductors; and suitable polymers such as poly-paraphenylene vinylene (PPV). For an OLED, the hole transport material may have a thickness from 100 to 500 Angstroms, and the emitter may have a thickness from 50 to 100 Angstroms. Further detail on suitable materials may be found in U.S. Pat. No. 5,703,436 and in U.S. Pat. No. 5,965,280, both of which are incorporated by reference in their entireties.

The electrodes 624 and 634 may be arrayed such that various parts of the light emitting material may be selectively actuated to luminesce. Further details regarding a suitable arrangement of electrodes may be found in the above-referenced U.S. Pat. No. 5,703,436.

The back panel 614 may include a flexible substrate 632 similar to the substrate 32 described above. The back panel 614 may also include an acrylic or other hard layer to facilitate laser ablation of the back electrodes 634. The back panel 614 may include a barrier coating, such as a multilayer barrier coating, to prevent contaminants, such as water and/or moisture, from entering.

Turning now to FIG. 16, an electroluminescent display device 710 (a passive matrix polymer light emitting device (PLED)) includes a microreplicated substrate film 712. The substrate film 712 has ridges or protrusions 714, and wells 716 between the ridges or protrusions 714. Each of the wells 716 is surrounded with four walls of the ridges 714, thereby forming a separate pixel. In each of the wells 716 are an anode 720, a hole transport layer 722, a light emitting polymer (LEP) 724, and a cathode 728. A rigid back panel 730 protects the back side of the display 710. The substrate film 712 and the back panel 730 are sealed by a sealant such as an epoxy resin (not shown in FIG. 16) to prevent moisture penetration into the display device 710.

The substrate film 712 may be polycarbonate, PET, or PES. The anode 720 is a transparent electrode, such as an ITO electrode or an electrode composed of silver or silver alloy. Formation of such transparent electrodes is described further in U.S. Pat. No. 5,667,853, which is incorporated herein by reference in its entirety. The hole transport layer 722 may include PEDOT/PSS material (polyethylene dioxy thiophene/polystyrene sulphonate), and may have a thickness from 20 to 60 nm. The LEP 724 may include poly (phenylene vinylene) derivatives, and may have a thickness of less than 200 nm. The cathode 728 may be a low work function electrode material, for example including Ca or Mg.

The back panel 730 may include glass, and may have an opaque coating such as a black coating or a metal coating to improve the contrast ratio of the display device 710. Alternatively, the back panel 730 may be uncoated, non-transparent (such as opaque) glass. As another alternative, the back panel 730 may be a polymer-metal laminate, such as the material for the back substrate 432 shown in FIG. 13 and described above. It will be appreciated that the polymer-metal laminate back panel may be part of a roll of such material.

The ridges or protrusions 714 may have straight sides (as shown in FIG. 16), or alternatively may have tapered sides (as shown in FIGS. 20–22, described below).

A potential difference between the anode 720 and the cathode 728 causes flow of electrons through the structure in the well 728, which causes the LEP 724 to emit light. This light passes through the transparent anode 720 and the transparent substrate film 712, and out of the display device 710.

The substrate film 712 may have one or more coatings to provide a barrier against contamination of the display device 710 by oxygen and/or moisture.

A process for making the display device 710 may include forming the anodes 720 in the wells 716 by sputtering ITO followed by laser etching or by sputtering with shadow masking during the sputtering. The hole transport layer 722 and the LEP 724 may by deposited by sequential ink jet printing of PEDOT and LEP into the wells 716. Then sputter coating of the cathodes 728 is followed by placement and sealing of the back panel 730.

More broadly, manufacture of the display 710 may include the following steps: 1) microreplicate the substrate film 712 to form the ridges 714 and the wells 716; 2) sputter coat the material for the anodes 720; 3) laser etch to remove the anode material from the tops and sides of the ridges 714; 4) inkjet print the hole transport layer 722 in the wells 716; 5) inkjet print the LEP 724 in the wells 716; 6) sputter deposit the material for the cathodes 728; 7) laser etch to remove the cathode material from the tops and sides of the ridges 714 (removing excess hole transport layer material and LEP as well); 8) printing the sealant; 9) laminating the back panel 730 onto the ridges 714 by a pick and place operation; 10) curing the sealant; and 11) cutting the finished display device 710, separating it from a roll including multiple such devices. Steps 1, 2, and 3 of the above process may each be performed separately, in one or more process lines separate from the production line for the remaining process. Alternatively or in addition, the sputter coating and/or laser etching steps may be performed separately. As another alternative, the ridges 714 may be formed by printing UV-curable material, followed by UV irradiation or photolithography.

It will be appreciated that suitable alternatives may be used for some of the above steps. For example, wet etching may be used instead of one or both of the laser etchings. As another example, sputtering deposition may be used instead of one or both of the inkjet printing processes.

An alternative passive matrix PLED display device 810 is shown in FIG. 17. Components/features 812–830 correspond to components/features 712–730 of the display device 710 shown in FIG. 16 and described above. However, in the display device 810 the light from the LEP 824 exits the display through the front panel 830. Thus the front panel 830 and the cathode 828 are sufficiently transparent to allow light to pass therethrough. The front panel may be transparent glass. The cathode 828 may be a low work function electrode material. Examples of transparent, low work function electrodes may be found in U.S. Pat. No. 6,150,043, which is incorporated herein by reference in its entirety.

The substrate film 812 forms part of the back panel of the display device 810. The substrate film 812 may be laminated to a metal foil 840, to provide good barrier properties and enhanced reflectivity and/or contrast. The metal foil 840 may be an aluminum foil, a copper foil, or a stainless steel foil, for example.

The anode 820 need not be transparent, and may be a patterned metal electrode, such as an electrode including aluminum, copper, or ITO, for example.

FIG. 18 shows an active matrix PLED 910. Except as discussed below, the components/features 912–940 may

correspond to the components/features of the display device 810 shown in FIG. 17 and described above.

The PLED 910 includes a continuous cathode layer 928. Each of the anodes 920 has a corresponding thin film transistor (TFT) 944. The TFT 944 is used in selectively providing power to the corresponding anode 920. The TFT may be a polysilicon TFT. Alternatively, the TFT 944 may be a printed organic semiconductor TFT.

The substrate film 912 may be coated with polyimide to improve thermal resistance. Polyimide-coated films are described further in International Publication WO 00/41884, which is incorporated herein by reference in its entirety.

Steps in manufacture of the display 910 may include the following steps: 1) microreplicate the substrate film 912 to form the ridges 914 and the wells 916; 2) sputter coat the material for the anodes 920; 3) laser etch to remove the anode material from the tops and sides of the ridges 914; 4) form the TFTs 944 in the wells 916; 5) inkjet print the hole transport layer 922 in the wells 916; 6) inkjet print the LEP 924 in the wells 916; 7) sputter deposit the material for the cathodes 928; 8) printing the sealant; 9) laminating the back panel 930 onto the ridges 914 by a pick and place operation; 10) curing the sealant; and 11) cutting the finished display device 910, separating it from a roll including multiple such devices.

FIGS. 19–23 illustrate some steps of a process for making the PLED devices such as those described above. FIG. 19 shows a substrate film 1012 with wells 1016 thereupon formed by microreplication. FIGS. 20 and 21 show cross-sections of the film, showing one possible tapered shape of the ridges 1014 bounding the wells 1016.

For passive matrix displays such as those of FIGS. 16 and 17, following deposition of the anode electrode material (e.g., ITO), the electrode material is selectively etched to remove it from the shaded areas 1050 shown in FIG. 22. As discussed above, the etching may be wet etching, for example utilizing patterning by a photolithography process to achieve the desired selective etching. Alternatively, the etching may be dry etching, such as excimer laser etching.

After deposition of the hole transporting and LEP layers, such as by printing, and before depositing the cathode material, an insulator, such as SiO_2, may be selectively deposited, for example being deposited in the shaded areas 1054 shown in FIG. 23. The insulator may reduce the occurrence of electrical shorting in the display device.

As another alternative manufacturing method, after microreplication of a substrate film such as the substrate film 1012, the bottom of the film may be cut off, thus transforming the wells 1016 into holes through the film. Then the film may be adhered to a glass or other rigid substrate with patterned electrodes (such as ITO electrodes) already formed thereupon. It will be appreciated that the substrate film 1012 may be suitable registered so as to desirably align the holes with the patterned electrodes.

Displays of the sort described above may be coupled to other components as a part of a wide variety of devices, for display of various types of information. For example, a display may be coupled to a microprocessor, as part of a computer, electronic display device such as an electronic book, cell phone, calculator, smart card, appliance, etc., for displaying information.

It will be appreciated that the devices and methods described above have many advantages over prior art devices. For instance, as already mentioned above, the use of the pick and place device to align the front panel 12 relative to the back panel 14 allows improved accuracy in alignment. Use of a glass front substrate 22 results in a better brightness and contrast than what is presently achieved with complete plastic displays. Use of a glass front substrate 22 in combination with an opaque back panel 14 also allows for high conductivity at low cost. The glass front substrate 22 may also advantageously act as a moisture and oxygen barrier, reducing or eliminating the need for multiple transparent barrier layer films.

Although the invention has been shown and described with respect to a certain embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described elements (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such elements are intended to correspond, unless otherwise indicated, to any element which performs the specified function of the described element (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one or more of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A display device comprising a front panel and a back panel with a light control material therebetween, wherein one of the panels has a rigid substrate and the other of the panels has a flexible substrate.

2. The display of claim 1, wherein the rigid substrate is a glass substrate and the flexible substrate is a plastic substrate.

3. The display of claim 2, wherein the glass substrate has a thickness from 0.2 mm to 1 mm.

4. The display of claim 1,

wherein the rigid substrate is a rigid plastic substrate; and

wherein the flexible substrate is a flexible plastic substrate.

5. The display of claim 1, wherein the flexible substrate is opaque.

6. The display of claim 5, wherein the flexible substrate is black.

7. The display of claim 5, wherein the back panel includes the flexible substrate, an opaque material layer, and a transparent layer.

8. The display of claim 7, wherein the flexible substrate includes the opaque material layer and the transparent layer.

9. The display of claim 8, wherein the opaque material layer and the transparent layer are both polymer material layers.

10. The display of claim 1, wherein one of the panels includes a sealant ring thereupon.

11. The display of claim 7, wherein the opaque material layer is a metallic later.

12. The display of claim 7, wherein the opaque material layer includes a conductive ink.

13. The display of claim 1, wherein one of the panels includes protrusions for supporting the substrates in a spaced-apart relationship.

14. The display of claim 13, wherein the protrusions include posts.

15. The display of claim 13, wherein the protrusions include ribs.

16. The display of claim 13, wherein the one of the panels includes a plurality of wells surrounded by ridges.

17. The display of claim 13, wherein the protrusions have straight sides.

18. The display of claim 13, wherein the protrusions have tapered sides.

19. The display of claim 13, wherein the protrusions are chemically and physically integral with the one of the panels.

20. The display of claim 13, wherein the protrusions are made of a curable resin.

21. The display of claim 1, further comprising spacers for supporting the substrates in a spaced-apart relationship.

22. The display of claim 1, wherein the flexible substrate includes driving electronics embedded therein.

23. The display of claim 22, wherein the driving electronics include microstructure elements.

24. The display of claim 22, wherein the driving electronics include thin film transistors.

25. The display of claim 1, wherein the panels includes respective front and back electrode arrays on the substrates.

26. The display of claim 25, wherein one of the electrode arrays includes transparent electrodes, and the other of the electrode arrays includes opaque electrodes.

27. The display of claim 26, wherein the transparent electrodes include indium tin oxide electrodes.

28. The display of claim 26, wherein the transparent electrodes include silver or an alloy thereof.

29. The display of claim 26, wherein the opaque electrodes include metal electrodes.

30. The display of claim 26, wherein one of the electrode arrays is a row electrode array, and the other of the arrays is a column electrode array.

31. The display of claim 1, wherein one of the panels includes an outer-shell protective layer.

32. The display of claim 31, wherein the protective layer functions as a moisture barrier.

33. The display of claim 31, wherein the outer protective layer functions as an oxygen barrier.

34. The display of claim 31, wherein the outer protective layer is a metallic film.

35. The display of claim 31, wherein the one of the panels also includes an internal protective layer.

36. The display of claim 35, wherein the internal protective layer includes an acrylic hard coat layer.

37. The display of claim 35, wherein the internal protective layer includes polymer material.

38. The display of claim 35, wherein the internal protective layer functions as a thermal protective layer during laser ablation.

39. The display of claim 1, wherein the flexible substrate includes a metal foil layer laminated to a plastic film.

40. The display of claim 39, wherein the metal foil layer has a thickness of 25 to 75 microns.

41. The display of claim 39, wherein the plastic film has a thickness of 50 to 200 microns.

42. The display of claim 39, further comprising a primer layer between the metal foil layer and the plastic film.

43. The display of claim 42, wherein the primer layer includes an acrylic coating.

44. The display of claim 42, wherein the primer layer has a thickness of 1 to 5 microns.

45. The display of claim 1, wherein the light control material is a light emitting material.

46. The display of claim 45, wherein the light emitting material includes a hole transport material.

47. The display of claim 46, wherein the hole transport material has a thickness from 100 to 500 Angstroms.

48. The display of claim 46, wherein the light emitting material further includes an electron transport material.

49. The display of claim 48, wherein the electron transport material has a thickness from 100 to 500 Angstroms.

50. The display of claim 46, wherein the light emitting material does not include an electron transport material.

51. The display of claim 46, wherein the light emitting material further includes an emitter.

52. The display of claim 51, wherein the emitter has a thickness from 50 to 100 Angstroms.

53. The display of claim 45, wherein the light emitting material includes a semiconductor material.

54. The display of claim 45, wherein the light emitting material includes an organic compound.

55. The display of claim 45, wherein the light emitting material includes a light emitting polymer.

56. The display of claim 55, wherein the light emitting polymer has a thickness from 20 to 60 nm.

57. The display of claim 45, further comprising anodes and cathodes on respective opposite sides of the light emitting material.

58. The display of claim 1, wherein the light control material is a liquid crystal material.

59. The display of claim 58, wherein the liquid crystal material includes a cholesteric liquid crystal material.

60. The display of claim 58, wherein the liquid crystal material includes a twisted nematic liquid crystal material.

61. The display of claim 58, wherein the liquid crystal material includes a zero field multistable cholesteric liquid crystal mix.

62. The display of claim 58, wherein the panels include respective alignment layers.

63. A display device comprising:

a front panel;

a back panel;

a light control material between the front panel and the back panel;

wherein one of the panels has a rigid substrate and the other of the panels has a flexible substrate;

wherein the light control material includes a light crystal material;

wherein the flexible substrate is opaque; and

wherein one of the panels includes protrusions for supporting the substrates in a spaced-apart relationship.

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APPENDIX D

US 20030178937A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0178937 A1**

Mishima (43) **Pub. Date: Sep. 25, 2003**

(54) **LIGHT-EMITTING DEVICE**

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(21) Appl. No.: **10/395,189**

(22) Filed: **Mar. 25, 2003**

(30) **Foreign Application Priority Data**

Mar. 25, 2002 (JP) 2002-084432

Publication Classification

(51) **Int. Cl.**[7] **H05B 33/04**; H05B 33/10

(52) **U.S. Cl.** **313/511**; 313/506

(57) **ABSTRACT**

A light-emitting device comprising an anode, one or more organic compound layers containing at least a light-emitting layer, and a transparent cathode on a flexible support substrate having a linear thermal expansion coefficient of 20 ppm/° C. or less, water permeability of 0.01 g/m^2·day or less, and oxygen permeability of 0.01 cc/m^2·day·atm or less. The flexible support substrate is constituted by a metal foil provided with an insulating layer on one or both surfaces thereof.

LIGHT-EMITTING DEVICE

FIELD OF THE INVENTION

[0001] The present invention relates to a light-emitting device usable for plate-shaped light sources such as full-color display devices, backlights and illumination light sources, light source arrays of printers, etc., particularly to a flexible, light-emitting device excellent in light-emitting luminance and durability.

BACKGROUND OF THE INVENTION

[0002] Promising as inexpensive, solid-emission-type, large-emission-area, full-color display devices and writing light source arrays, the organic, light-emitting devices have been actively developed. The organic, light-emitting device generally comprises a couple of electrodes, and a light-emitting layer formed therebetween. When an electric field is applied to both electrodes, electrons are injected from the cathode, while holes are injected from the anode. When electrons and holes are recombined in the light-emitting layer, whereby an energy level is lowered from a conduction band to a valence band, energy is turned to light, which is emitted from the organic, light-emitting device.

[0003] The conventional organic, light-emitting devices are disadvantageous in that they require high driving voltage for light emission and are poor in luminance and light-emitting efficiency. Some proposals have recently been provided to overcome the above disadvantages. For example, a light-emitting device comprising organic thin layers formed by vapor-depositing organic compounds is disclosed in Applied Physics Letters, 51, 913 (1987). This organic, light-emitting device has a two-layer laminate structure comprising an electron-transporting layer and a hole-transporting layer, exhibiting largely improved light-emitting properties than those of conventional organic, light-emitting devices having a single-layer structure. This organic, light-emitting device uses a low-molecular-weight amine compound as a hole-transporting material and 8-quinolinol aluminum complex (Alq) as an electron-transporting, light-emitting material, emitting green light. After this disclosure, many organic, light-emitting devices comprising vapor-deposited organic thin layers have been reported, as disclosed in Macromolecularly Symposium, 125, 1 (1997) and references therein, etc.

[0004] For the purpose of production cost reduction and application to flexible large-area devices such as backlights and illumination light sources, organic, light-emitting devices formed from high-molecular-weight, light-emitting compounds by a wet film-forming method have also been reported. As the high-molecular-weight, light-emitting compounds, there are, for instance, poly(p-phenylenevinylene) generating green light (Nature, Vol. 347, page 539, 1990), poly(3-alkylthiophene) generating reddish orange light (The Japanese Journal of Applied Physics, Vol. 30, page L 1938, 1991), polyalkylfluorene generating blue light (The Japanese Journal of Applied Physics, Vol.30, page L1941, 1991), etc. Also, JP 2-223188 A reports an attempt to disperse low-molecular-weight, light-emitting compounds in binder resins, and wet-coat the resultant dispersion to form films.

[0005] However, in any of light-emitting devices produced by the above dry method and those produced by the above wet method, the use of a flexible, plastic substrate provides extremely lower durability than the use of a glass substrate. Accordingly, it has been considered difficult to provide commercially acceptable light-emitting devices by the wet method. One of the reasons therefor is that a plastic substrate of PET, etc. has such large gas permeability and moisture permeability that the penetrating oxygen and moisture exert adverse effects on the performance of the light-emitting device. When moisture exists in the light-emitting device, current flowing therein electrolyzes the moisture, generating a hydrogen gas and an oxygen gas and thus resulting in dark spots. In addition, because extremely easily oxidizable metals are used for the cathode, they are reacted with moisture and oxygen, causing dark spots.

[0006] Another reason is that because there is difference in a linear thermal expansion coefficient by one order or more between the flexible, plastic substrate and the electrode materials (ITO and metals), electrode materials tend to peel off from the substrate due to a thermal hysteresis, resulting in cracking and decrease in the durability of the light-emitting device.

[0007] A further reason is that because the substrate should be substantially transparent for the reason that the light-emitting device has a basis structure of substrate/anode/organic compound layer/cathode, in which the emitted light is taken out from the anode substrate side, there has not been developed yet a flexible support substrate that is transparent and has as high barrier properties to moisture and oxygen as those of glass. For instance, JP 2001-185348 A proposes a sealing layer comprising an insulating layer laminated with a metal layer to have high barrier properties to moisture and oxygen. However, this is a sealing layer that cannot be used as a substrate. Though JP 2001-60495 A and JP 11-320744 A describe the linear thermal expansion coefficients of barrier layers and protective films, they fail to describe the linear thermal expansion coefficients of flexible support substrates.

OBJECT OF THE INVENTION

[0008] Accordingly, an object of the present invention is to provide a flexible, light-emitting device excellent in durability, light-emitting efficiency and luminance, and usable for plate-shaped light sources such as full-color display devices, backlights and illumination light sources, light source arrays of printers, etc.

SUMMARY OF THE INVENTION

[0009] As a result of intense research in view of the above objects, the inventor has found that by utilizing a device structure (top emission-type), in which the emitted light is taken out from the opposite side to the substrate, and by using a flexible support substrate having as high gas barrier as that of glass, it is possible to obtain a flexible, light-emitting device having excellent luminance and durability. The present invention has been accomplished by this finding.

[0010] Thus, the light-emitting device of the present invention comprises an anode, one or more organic compound layers containing at least a light-emitting layer, and a transparent cathode on a flexible support substrate having gas barrier properties, the flexible support substrate having a linear thermal expansion coefficient of 20 ppm/° C. or less.

[0011] The flexible support substrate preferably has water permeability of 0.01 g/m^2·day or less and oxygen permeability of 0.01 cc/m^2·day·atm or less.

[0012] The flexible support substrate is preferably constituted by a metal foil provided with an insulating layer on one or both surfaces thereof. The metal foil is preferably an aluminum foil or a copper foil. The insulating layer is preferably made of a metal oxide and/or a metal nitride. Preferable specific examples of materials for the insulating layer include polyimides.

[0013] The flexible support substrate has a linear thermal expansion coefficient of preferably 10 ppm/° C. or less, more preferably 8 ppm/° C. or less.

[0014] The insulating layer is preferably made of a plastic selected from the group consisting of polyesters, polystyrenes, polycarbonates, polyether sulfones, polyarylates, allyldiglycolcarbonates, polyimides, polycyclolefins, norbornene resins and poly(chlorotrifluoroethylene).

[0015] The insulating layer constituted by a plastic sheet preferably has a thickness of about 10 to about 200 μm. The thickness of the metal foil is about 10 μm to about 100 μm. The thickness of the inorganic insulating layer is about 10 nm to about 1000 nm.

[0016] The insulating layer is preferably at least one of metal oxide and metal nitride.

[0017] The metal oxide is selected from the group consisting of silicon oxide, germanium oxide, zinc oxide, aluminum oxide and titanium oxide, and copper oxide, and wherein the metal nitride is selected from the group consisting of silicon nitride, germanium nitride and aluminum nitride.

[0018] The metal foil has an insulating layer made of plastics on one surface, and an insulating layer made of made of at least one of metal oxide and metal nitride on the other surface.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] The light-emitting device of the present invention has a layer structure comprising a flexible support substrate/an anode/an organic compound layer/a transparent cathode.

[0020] [1] Flexible Support Substrate (Support Substrate)

[0021] The support substrate used in the present invention has flexibility and gas barrier properties, and its linear thermal expansion coefficient is 20 ppm/° C. (20×10^{-6}/° C.) or less, preferably 10 ppm/° C. or less, more preferably 8 ppm/° C. or less. The linear thermal expansion coefficient is a change ratio of the length of a sample when heated at a constant speed, which is determined from measurement results by a thermomechanical analysis (TMA) method. When the linear thermal expansion coefficient is larger than 20 ppm/° C., cracking and peeling may occur in an electrode at the time of heating during a thermal hysteresis, whereby the durability of the light-emitting device is likely to be deteriorated. Materials having linear thermal expansion coefficients of 20 ppm/° C. or less include metal foils such as an aluminum foil, a copper foil, a stainless steel foil, a gold foil, a silver foil, and plastic sheets made of polyimides, liquid crystal polymers, etc.

[0022] The support substrate preferably has water permeability of 0.01 g/m^2·day or less, and oxygen permeability of 0.01 cc/m^2·day·atm or less. The water permeability may be measured by a method according to JIS K 7129B (1992), typically by an MOCON method (isostatic method). The oxygen permeability may be measured by a method according to JIS K 7126B (1987), typically by an MOCON method (isostatic method). With the water permeability and oxygen permeability of the support substrate kept at the above levels, it is possible to prevent moisture and oxygen causing the deterioration of durability from entering into the light-emitting device.

[0023] As a flexible support substrate satisfying the above property conditions without short-circuiting when producing a light-emitting device with an electrode, a substrate constituted by a metal foil provided with an insulating layer on one or both surfaces thereof is preferable. The metal foil is not particularly restrictive but may be an aluminum foil, a copper foil, a stainless steel foil, a gold foil, a silver foil, etc. preferable among them from the aspects of the easiness of working and cost is an aluminum foil or a copper foil. The metal foil is preferably as thick as 10 to 100 μm. When the metal foil is thinner than 10 μm, the resultant support substrate has large moisture and oxygen permeability, resulting in poor gas barrier properties, leading to a light-emitting device with poor durability. On the other hand, when the metal foil is thicker than 100 μm, the resultant support substrate has insufficient flexibility, resulting in inconvenience in handling.

[0024] Though not particularly restrictive, the insulating layer bonded to one or both surfaces of the metal foil may be made, for instance, of inorganic materials such as inorganic oxides, inorganic nitrides, etc.; plastics such as polyesters (polyethylene terephthalate, polybutylene terephthalate, polyethylene naphthalate, etc.), polystyrenes, polycarbonates, polyether sulfones, polyarylates, allyldiglycolcarbonates, polyimides, polycyclolefins, norbornene resins, poly(chlorotrifluoroethylene), etc. Because a metal cathode is formed on the insulating layer, it is preferable that the insulating layer has a linear thermal expansion coefficient close to those of the metal cathode and the metal foil. From this aspect, too, the insulating layer preferably has a linear thermal expansion coefficient of 20 ppm/° C. or less. If larger than this, cracking and peeling take place while heating, causing the deterioration of durability.

[0025] As the inorganic, insulating layer having a linear thermal expansion coefficient of 20 ppm/° C. or less, metal oxides such as silicon oxide, germanium oxide, zinc oxide, aluminum oxide, titanium oxide, copper oxide; metal nitrides such as silicon nitride, germanium nitride, aluminum nitride are preferable, which may be-used alone or in combination.

[0026] The thickness of the inorganic, insulating layer is preferably 10 nm to 1000 nm. When the inorganic, insulating layer is thinner than 10 nm, it provides only low insulation. On the other hand, when the inorganic, insulating layer is thicker than 1,000 nm, cracking easily occurs in the support substrate, resulting in pinholes and thus decrease in insulation.

[0027] The method for forming the insulating layer from metal oxides and/or metal nitrides is not particularly restrictive, but dry methods such as a vapor deposition method, a

sputtering method, a CVD method, etc., wet methods such as a sol-gel method, etc., coating methods using dispersions of particles of metal oxides and/or metal nitrides in solvents, etc. may be used.

[0028] As plastic materials for the insulating layer having a linear thermal expansion coefficient of 20 ppm/° C. or less, polyimide is particularly preferable. When polyimide is used for the insulating layer, a polyimide sheet is preferably laminated with an aluminum foil. The polyimide sheet preferably has a thickness of 10 to 200 μm. When the polyimide sheet is thinner than 10 μm, handling is difficult at the time of lamination. On the other hand, when the polyimide sheet is thicker than 200 μm, the flexibility is deteriorated, resulting in inconvenience in handling.

[0029] Though the insulating layer may be formed only on one surface of the metal foil, it may be formed on both surfaces. When formed on both surfaces, any of the insulating layers on both surfaces may be made of metal oxides and/or metal nitrides, or may be a plastic insulating layer such as a polyimide sheet. Alternatively, the insulating layer on one surface is made of metal oxides and/or metal nitrides, while the insulating layer on the other surface is an insulating polyimide sheet.

[0030] The support substrate thus produced as described above is small in both water permeability and oxygen permeability and has excellent flexibility. The shape, structure, size, etc. of the flexible support substrate is not particularly restrictive, but may be properly selected depending on the applications, purposes, etc. of the light-emitting device. The support substrate is generally in a plate shape.

[0031] [2] Anode

[0032] The anode need only have a function as a usual anode supplying holes to the organic compound layer, and its shape, structure, size, etc. are not particularly restrictive but may be properly selected from those of known electrodes depending on the applications and purposes of the light-emitting device.

[0033] Materials for the anode may be, for instance, metals or their alloys, metal oxides, electrically conductive, organic compounds, or mixtures thereof, preferably having a work function of 4 eV or more. Specific examples of the materials for the anode include conductive metal oxides such as antimony-doped tin oxide (ATO), fluorine-doped tin oxide (FTO), tin oxide, zinc oxide, indium oxide, indium tin oxide (ITO), indium zinc oxide (IZO); metals such as gold, silver, chromium and nickel; mixtures and laminates of the metals and conductive metal oxides; inorganic, conductive compounds such as copper iodide and copper sulfide; dispersions of conductive metal oxides or metal compounds; organic, conductive compounds such as polyaniline, polythiophene and polypyrrole; laminates of the organic, conductive compounds and ITO; etc.

[0034] The method for forming the anode on the support substrate may be appropriately selected from wet methods such as a printing method and a coating method; physical methods such as a vacuum deposition method, a sputtering method and an ion-plating method; chemical methods such as a CVD method and a plasma CVD method; etc., depending on the materials used therefor. For example, when the anode is made of ITO, it may preferably be formed by a DC or RF sputtering method, a vapor deposition method, an ion-plating method, etc. In addition, when the anode is made of an organic, conductive compound, it may be formed by a wet method. The anode is preferably formed by a wet method from the aspects of increase in the area of the light-emitting device and productivity.

[0035] The patterning of the anode layer may be conducted by a chemical etching method such as a photolithography method, a physical etching method using laser beams, a vacuum vapor deposition method or a sputtering method with a mask, a lift-off method, a printing method, etc.

[0036] The thickness of the anode layer may be properly controlled depending on the material used therefor. The thickness of the anode layer is generally 10 nm to 50 μm, preferably 50 nm to 20 μm. The resistance of the anode is preferably 10^6 Ω/square or less, more preferably 10^5 Ω/square or less. In the case of 10^5 Ω/square or less, the formation of bus line electrodes can provide a large-area, light-emitting device with excellent performance. Because the emitted light is taken out from a transparent cathode in the light-emitting device of the present invention, the anode may be colorless transparent, colored transparent or opaque.

[0037] [3] Organic Layer (Organic Compound Layer)

[0038] The organic compound layer is constituted by one or more layers including at least a light-emitting layer. The specific layer structure of the light-emitting device of the present invention may be as follows:

[0039] (a) Anode/light-emitting layer/transparent cathode;

[0040] (b) Anode/light-emitting layer/electron-transporting layer/transparent cathode;

[0041] (c) Anode/hole-transporting layer/light-emitting layer/electron-transporting layer/transparent cathode;

[0042] (d) Anode/hole-transporting layer/light-emitting layer/transparent cathode;

[0043] (e) Anode/light-emitting layer/electron-transporting layer/electron-injecting layer/transparent cathode; and

[0044] (f) Anode/hole-injecting layer/hole-transporting layer/light-emitting layer/electron-transporting layer/electron-injecting layer/transparent cathode; etc.

[0045] (1) Light-Emitting layer

[0046] The light-emitting layer comprises at least one light-emitting material, and may contain, if necessary, a hole-transporting material, an electron-transporting material and a host material. The light-emitting material is not restrictive as long as it is a fluorescent compound or a phosphorescent compound.

[0047] Examples of the fluorescent compound used in the present invention include benzoxazole derivatives; benzoimidazole derivatives; benzothiazole derivatives; styrylbenzene derivatives; polyphenyl derivatives; diphenylbutadiene derivatives; tetraphenylbutadiene derivatives; naphthalimido derivatives; coumarin derivatives; perylene derivatives; perynone derivatives; oxadiazole derivatives; aldazine derivatives; pyralidine derivatives; cyclopentadiene derivatives; bis(styryl)anthracene derivatives; quinacri-

don derivatives; pyrrolopyridine derivatives; thiadiazolopyridine derivatives; styrylamine derivatives; aromatic dimethylidine compounds; metal complexes such as 8-quinolinol metal complexes and derivatives thereof and rare-earth metal complexes; light-emitting polymer materials such as polythiophene derivatives, polyphenylene derivatives, polyphenylenevinylene derivatives and polyfluorene derivatives; etc. The fluorescent compounds may be used alone or in combination.

[0048] The phosphorescent compound is preferably an ortho-metallated complex or a porphyrin complex.

[0049] The ortho-metallated complexes used in the present invention may be such compounds that are described in Akio Yamamoto, "Metalorganic Chemistry, Foundation and Application," pages 150 to 232, Shokabo Publishing Co., Ltd., (1982); H. Yersin, "Photochemistry and Photophysics of Coordination Compounds," pages 71 to 77 and 135 to 146, Springer-Verlag, Inc. (1987), etc. The organic compound layer comprising such an ortho-metallated complex is excellent in luminance and light-emitting efficiency.

[0050] Ligands forming the ortho-metallated complexes are described in the above references. Preferable ligands among them include 2-phenylpyridine derivatives, 7,8-benzoquinoline derivatives, 2-(2-thienyl) pyridine derivatives, 2-(1-naphthyl) pyridine derivatives and 2-phenylquinoline derivatives, etc. If necessary, the derivatives may have substituents. The ortho-metallated complexes may have other ligands than the above ligands.

[0051] The ortho-metallated complexes used in the present invention may be synthesized by known methods disclosed in Inorg. Chem., 30, 1685, 1991; Inorg. Chem., 27, 3464, 1988; Inorg. Chem., 33, 545, 1994; Inorg. Chim. Acta, 181, 245, 1991; J. Organomet. Chem., 335, 293, 1987; J. Am. Chem. Soc., 107, 1431, 1985; etc.

[0052] Preferable among the ortho-metallated complexes are compounds emitting light from triplet excitons from the aspect of improvement in light-emitting efficiency. Preferable among the porphyrin complexes is a porphyrin-platinum complex. The phosphorescent compounds may be used alone or in combination. The fluorescent compound and the phosphorescent compound may be used together. From the aspects of luminance and light-emitting efficiency, it is preferable to use the phosphorescent compound.

[0053] Though not restrictive, the hole-transporting materials may be low- or high-molecular-weight materials if they have any of functions of injecting holes from the anode, transporting holes and blocking electrons from the cathode. Examples of the hole-transporting materials include carbazole derivatives, triazole derivatives, oxazole derivatives, oxadiazole derivatives, imidazole derivatives, polyarylalkane derivatives, pyrazoline derivatives, pyrazolone derivatives, phenylenediamine derivatives, arylamine derivatives, amino-substituted chalcone derivatives, styrylanthracene derivatives, fluorenone derivatives, hydrazone derivatives, stilbene derivatives, silazane derivatives, aromatic tertiary amine compounds, styrylamine compounds, aromatic dimethylidyne compounds, porphyrin compounds, polysilane compounds, poly(N-vinylcarbazole) derivatives, aniline copolymers, electrically conductive oligomers such as oligothiophenes, electrically conductive polymers such as polythiophene derivatives, polyphenylene derivatives, polyphenylenevinylene derivatives, polyfluorene derivatives, etc. These hole-transporting materials may be used alone or in combination. The content of the hole-transporting materials in the light-emitting layer is preferably 0 to 99.9% by mass, more preferably 0 to 80% by mass.

[0054] The electron-transporting materials are not particularly limited as long as they have any of functions of transporting electrons and blocking holes from the anode. Examples of the electron-transporting materials include triazole derivatives, oxazole derivatives, oxadiazole derivatives, fluorenone derivatives, anthraquinodimethane derivatives, anthrone derivatives, diphenylquinone derivatives, thiopyran dioxide derivatives, carbodimide derivatives, fluorenylidenemethane derivatives, distyrylpyrazine derivatives, anhydrides derived from heterocyclic tetracarboxylic acids having skeleton structures such as naphthaleneperylene, phthalocyanine derivatives, 8-quinolinol metal complexes and derivatives thereof, metallophthalocyanines, metal complexes containing a benzoxazole or benzothiazole ligand, aniline copolymers, electrically conductive oligomers such as oligothiophenes, electrically conductive polymers such as polythiophene derivatives, polyphenylene derivatives, polyphenylenevinylene derivatives, polyfluorene derivatives, etc. The content of the electron-transporting materials in the light-emitting layer is preferably 0 to 99.9% by mass, more preferably 0 to 80% by mass.

[0055] The host compound is a compound causing energy transfer from its excited state to the light-emitting compound, resulting in accelerating the light emission of a light-emitting compound such as a fluorescent compound and a phosphorescent compound. The host materials may be appropriately selected depending on the purposes without particular restrictions, as long as they are compounds capable of moving exciton energy to the light-emitting materials. Specific examples of the host compounds include carbazole derivatives, triazole derivatives, oxazole derivatives, oxadiazole derivatives, imidazole derivatives, polyarylalkane derivatives, pyrazoline derivatives, pyrazolone derivatives, phenylenediamine derivatives, arylamine derivatives, amino-substituted chalcone derivatives, styrylanthracene derivatives, fluorenone derivatives, hydrazone derivatives, stilbene derivatives, silazane derivatives, aromatic tertiary amine compounds, styrylamine compounds, aromatic dimethylidyne compounds, porphyrin compounds, anthraquinodimethane derivatives, anthrone derivatives, diphenylquinone derivatives, thiopyran dioxide derivatives, carbodimide derivatives, fluorenylidenemethane derivatives, distyrylpyrazine derivatives, anhydrides derived from heterocyclic tetracarboxylic acids having skeleton structures such as naphthaleneperylene, phthalocyanine derivatives, 8-quinolinol metal complexes and derivatives thereof, metallophthalocyanines, metal complexes containing a benzoxazole or benzothiazole ligand, polysilane compounds, poly(N-vinylcarbazole) derivatives, aniline copolymers, electrically conductive oligomers such as oligothiophenes, electrically conductive polymers such as polythiophene derivatives, polyphenylene derivatives, polyphenylenevinylene derivatives, polyfluorene derivatives, etc. The host compounds may be used alone or in combination. The content of the host compound in the light-emitting layer is preferably 0 to 99.9% by mass, more preferably 0 to 99.0% by mass.

[0056] As other components in the light-emitting layer, electrically inactive polymer binders may be used if necessary. Examples of the electrically inactive polymer binders include polyvinyl chloride, polycarbonates, polystyrene, polymethyl methacrylate, polybutyl methacrylate, polyesters, polysulfones, polyphenylene oxide, polybutadiene, hydrocarbon resins, ketone resins, phenoxy resins, polyamides, ethyl cellulose, polyvinyl acetate, ABS resins, polyurethanes, melamine resins, unsaturated polyesters, alkyd resins, epoxy resins, silicone resins, polyvinyl butyral, polyvinyl acetal, etc. The light-emitting layer containing a polymer binder is advantageous to be formed with a large area by the wet film-forming method.

[0057] (2) Other Organic Compound Layer

[0058] The light-emitting device of the present invention may be provided with other organic compound layers, if necessary. For instance, a hole-injecting layer and a hole-transporting layer may be inserted between the anode and the light-emitting layer, and an electron-transporting layer and an electron-injecting layer may be inserted between the light-emitting layer and the cathode. The above hole-transporting materials may be used for the hole-transporting layer and the hole-injecting layer, and the above electron-transporting materials may be used for the electron-transporting layer and the electron-injecting layer.

[0059] (3) Formation of Organic Compound Layer

[0060] The organic compound layer may be formed by any of methods of dry film-forming methods such as a vapor deposition method and a sputtering method; wet film-forming methods such as a dipping method, a spin coating method, a dip-coating method, a casting method, a die-coating method, a roll-coating method, a bar-coating method and a gravure-coating method; transferring methods; and printing methods. The film-forming methods may be appropriately selected depending on the materials of the organic compound layer.

[0061] Among them, the wet film-forming methods are advantageous in that they can easily form a large-area, organic compound layer, thereby efficiently providing the light-emitting device with high luminance and excellent light emission efficiency at a low cost. In the case of the wet film-forming methods, drying is properly carried out after the formation of film layers. Though the drying conditions are not particularly restrictive, such conditions as temperature, etc. are preferably selected such that coated layers are not damaged.

[0062] When the organic compound layer is formed by a wet film-forming method, it is preferable to add a binder resin to the organic compound layer. Examples of the binder resins include polyvinyl chloride, polycarbonates, polystyrene, polymethyl methacrylate, polybutyl methacrylate, polyesters, polysulfones, polyphenylene oxide, polybutadiene, hydrocarbon resins, ketone resins, phenoxy resins, polyamides, ethyl cellulose, polyvinyl acetate, ABS resins, polyurethanes, melamine resins, unsaturated polyesters, alkyd resins, epoxy resins, silicone resins, polyvinyl butyral, polyvinyl acetal, etc. The binder resins may be used alone or in combination.

[0063] In the wet forming of the organic compound layer, solvents used for the preparation of coating liquids by dissolving materials for the organic compound layer are not particularly restrictive, but may be properly selected depending on the types of the hole-transporting materials, the ortho-metallated complexes, the host materials, the polymer binders, etc. Specific examples of the solvents include halogen solvents such as chloroform, tetrachloromethane, dichloromethane, 1,2-dichloroethane and chlorobenzene; ketone solvents such as acetone, methyl ethyl ketone, diethyl ketone, n-propyl methyl ketone and cyclohexanone; aromatic solvents such as benzene, toluene and xylene; ester solvents such as ethyl acetate, n-propyl acetate, n-butyl acetate, methyl propionate, ethyl propionate, γ-butyrolactone and diethyl carbonate; ether solvents such as tetrahydrofuran and dioxane; amide solvents such as dimethylformamide and dimethylacetamide; dimethylsulfoxide, water; etc.

[0064] A solid content of the coating solution for the organic compound layer is not particularly restrictive, and its viscosity may be arbitrarily selected depending on a wet film-forming method. When the other organic compound layers are easily soluble in solvents, lamination is difficult. Accordingly, it is preferable to use a transfer method to form the organic compound layer.

[0065] [4] Transparent Cathode

[0066] The transparent cathode need only function as an electrode injecting electrons into the organic compound layer, and be substantially transparent to light, without particular restrictions in its shape, structure, size, etc. Known electrodes may be properly selected as the transparent cathode depending on the applications and purposes of the light-emitting device.

[0067] Though the transparent cathode may have a single-layer structure, it preferably has a two-layer structure consisting of a thin metal layer and a transparent, conductive layer, to meet both requirements of electron injection and transparency. Metals or alloys thereof used for the thin metal layer preferably have a work function of 4.5 eV or less. Examples of the materials used for the transparent cathode include alkali metals such as Li, Na, K and Cs; alkaline earth metals such as Mg and Ca; gold; silver; lead; aluminum; a sodium-potassium alloy; a lithium-aluminum alloy; a magnesium-silver alloy; indium; rare earth metals such as ytterbium; etc. Although the materials may be used alone, the rear-surface electrode is preferably made of a plurality of materials to improve both of stability and electron injection property.

[0068] Preferable among the above materials are alkali metals and alkaline earth metals from the viewpoint of the electron injection property, and aluminum-based materials from the viewpoint of stability during storage. Usable as the aluminum-based materials are aluminum itself and aluminum-based alloys and mixtures containing 0.01 to 10% by mass of alkali metals or alkaline earth metals, such as a lithium-aluminum alloy, a magnesium-aluminum alloy, etc.

[0069] The materials of thin metal layers usable for the transparent cathode are disclosed in JP 2-15595 A and JP 5-121172 A. The thin metal layer preferably has a thickness of 1 nm to 50 nm. When the thickness of the thin metal layer is less than 1 nm, it is difficult to form a uniformly thin metal layer. On the other hand, when the thickness of the thin metal layer exceeds 50 nm, the transparency of the thin metal layer decreases.

[0070] When the transparent cathode has a two-layer structure, materials used for the transparent, conductive layer are not particularly restrictive as long as they are transparent materials having conductivity or semi-conductivity, and the materials used for the above anode may suitably be used. Preferable among them are, for instance, antimony-doped tin oxide (ATO), fluorine-doped tin oxide (FTO), tin oxide, zinc oxide, indium oxide, indium tin oxide (ITO), indium zinc oxide (IZO), etc. The thickness of the transparent, conductive layer is preferably 30 nm to 500 nm. When the transparent, conductive layer is thinner than 30 nm, it is poor in conductivity or semi-conductivity. On the other hand, when it is thicker than 500 nm, the productivity is poor.

[0071] The formation method of the transparent cathode is not restrictive, but known methods may be used, though it is preferably carried out in a vacuum apparatus. It may be properly selected, for instance, from physical methods such as a vacuum deposition method, a sputtering method and an ion-plating method; chemical methods such as a CVD method and a plasma CVD method; etc, taking into consideration adaptability with the materials of the transparent cathode. For instance, when metals are selected as cathode materials, thin cathodes can be formed by sputtering one or more metals simultaneously or successively.

[0072] The patterning of the transparent cathode may be conducted by a chemical etching method such as a photolithography method, a physical etching method using laser beams, a vacuum vapor deposition method or a sputtering method with a mask, a lift-off method, a printing method, etc.

[0073] A dielectric layer may be formed between the transparent cathode and the organic compound layer. The dielectric layer may be made of a fluorinated alkali or alkaline earth metal, having a thickness of 0.1 nm to 5 nm. The dielectric layer may be formed by a vacuum vapor deposition method, a sputtering method, an ion-plating method, etc.

[0074] [5] Other Layers

[0075] Other layers such as a protective layer, etc. may properly be included depending on applications and purposes of the light-emitting device.

[0076] Preferable examples used as the protective layer are described in JP 7-85974 A, JP 7-192866 A, JP 8-22891 A, JP 10-275682 A, JP 10-106746 A, etc. The protective layer may be made of any material that can prevent substances such as water and oxygen degrading the function of the light-emitting device from entering or penetrating into the device. Silicon monoxide, silicon dioxide, germanium monoxide, germanium dioxide, etc. may be used for the protective layer. The shape, size and thickness of the protective layer may be selected depending on applications and purposes.

[0077] Though not restrictive, the protective layer may be formed by a vacuum deposition method, a sputtering method, an activated sputtering method, a molecular beam epitaxy method, a cluster ion beam method, an ion-plating method, a plasma polymerization method, a plasma CVD method, a laser CVD method, a thermal CVD method, a coating method, etc.

[0078] A sealing layer is preferably formed in the light-emitting device to prevent water and oxygen from entering or permeating into each layer of the device. Examples of materials for the sealing layer include copolymers of tetrafluoroethylene and at least one comonomer, fluorine-containing copolymers having cyclic structures in their main chains, polyethylene, polypropylene, polymethyl methacrylate, polyimides, polyureas, polytetrafluoroethylene, polychlorotrifluoroethylene, polydichlorodifluoroethylene, copolymers of chlorotrifluoroethylene or dichlorodifluoroethylene, moisture-resistant substances having a water absorption of 0.1% or less, metals such as In, Sn, Pb, Au, Cu, Ag, Al, Ti and Ni, metal oxides such as MgO, SiO, SiO_2, Al_2O_3, GeO, NiO, CaO, BaO, Fe_2O_3, Y_2O_3 and TiO_2, metal fluorides such as MgF_2, LiF, AlF_3 and CaF_2, liquid fluorinated solvents such as perfluoroalkanes, perfluoroamines and perfluoroethers, dispersions prepared by adding substances for adsorbing moisture or oxygen to liquid fluorinated solvents, etc.

[0079] Further, a water-absorbing agent or an inert liquid may be filled between the light-emitting structure and the sealing parts. Though not restrictive, the water-absorbing agents may be barium oxide, sodium oxide, potassium oxide, calcium oxide, sodium sulfate, calcium sulfate, magnesium sulfate, phosphorus pentoxide, calcium chloride, magnesium chloride, copper chloride, cesium fluoride, niobium fluoride, calcium bromide, vanadium bromide, a molecular sieve, zeolite, magnesium oxide, etc. Though not restrictive, the inert liquids may be paraffins, liquid paraffins, fluorine-containing solvents such as perfluoroalkanes, perfluoroamines and perfluorethers; chlorine-containing solvents; a silicone oil, etc.

[0080] The light-emitting device of the present invention may emit light by applying DC voltage or current to the anode and the cathode. DC voltage is generally 2 to 40 V and may contain an AC component, if necessary. Driving methods for the light-emitting devices are described in detail in JP 2-148687 A, JP 6-301355 A, JP 5-29080 A, JP 7-134558 A, JP 8-234685 A, JP 8-241047 A, U.S. Pat. Nos. 5,828,429 and 6,023,308, Japanese Patent 2,784,615, etc.

[0081] The present invention will be explained in further detail by Examples below without intention of restricting the scope of the present invention defined by the claims attached hereto.

EXAMPLE 1

[0082] A 50-μm-thick polyimide film (UPILEX-50S, available from Ube Industries, Ltd.) was laminated onto both surfaces of a 5-cm-each aluminum foil (thickness: 30 μm) by an adhesive, to produce a support substrate. TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 10 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, 25° C., 90% RH), and oxygen permeability of 0.01 cc/m^2·day·atm or less (MOCON method, 25° C., 0% RH).

[0083] A 250-nm-thick ITO layer with an indium/tin molar ratio of 95/5 was formed on this support substrate by a DC magnetron sputtering method to produce an anode. The anode had resistance of 7 Ω/square.

[0084] N,N'-dinaphthyl-N,N'-diphenylbenzidine was vapor-deposited on this anode in vacuum at a speed of 1

nm/second, to produce a 0.04-μm-thick, hole-transporting layer. Tris(2-phenylpyridine) iridium complex as an orthometallated complex, and 4,4'-N,N'-dicarbazole-biphenyl as a host material were vapor-deposited on this hole-transporting layer at speeds of 0.1 nm/second and 1 nm/second, respectively, to obtain a 0.024-μm-thick, light-emitting layer made of phosphorescent materials.

[0085] 2,2',2"-(1,3,5-benzenetriyl)tris[3-(2-methylphenyl)-3H-imidazo[4,5-b]pyridine] was vapor-deposited as an electron-transporting material on this light-emitting layer at a speed of 1 nm/second, to produce a 0.024-μm-thick, electron-transporting layer. A 3-nm-thick LiF layer was formed by a vapor deposition method on the organic compound layer thus obtained, to produce an electron-injecting layer.

[0086] Further, Al was vapor-deposited in a thickness of 10 nm to form a thin metal layer for a transparent cathode. A 200-nm-thick ITO layer with an indium/tin molar ratio of 95/5was formed thereon by a DC magnetron sputtering method to form a transparent, conductive layer, thereby obtaining a transparent cathode.

[0087] Aluminum lead wires were connected to the anode and the cathode, respectively. A sealing film was formed by silicon nitride by a sputtering method to cover other portions than the lead wires.

[0088] A light-emitting device thus obtained was evaluated by the following method. DC voltage was applied to each organic EL device by Source-Measure Unit 2400 available from Toyo Corporation to cause light emission. L_{max} represents the maximum luminance, and V_{max} represents voltage when L_{max} was obtained. The light-emitting efficiency (η_{200}) at 200 Cd/m^2 was regarded as external quantum efficiency. The results are shown in Table 1.

[0089] As a continuous driving test, this light-emitting device was caused to continuously emit light at an initial luminance of 200 Cd/m^2, to measure a time period ($t_{1/2}$), in which the luminance became half. As a storing test under humid and hot conditions, after the light-emitting device was stored under the conditions of 85° C. and 90% RH for 30 days, the maximum luminance $L_{max(30)}$ and voltage $V_{max(30)}$ at $L_{max(30)}$ were measured. The results are shown in Table 1.

EXAMPLE 2

[0090] A light-emitting device was produced and evaluated in the same manner as in Example 1 except for using a copper foil (thickness: 50 μm) in place of the aluminum foil. The results are shown in Table 1. The TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 8 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, under the same conditions as in Example 1), and oxygen permeability of 0.01 cc/m^2·day·atm or less (MOCON method, under the same conditions as in Example 1).

EXAMPLE 3

[0091] A light-emitting device was produced and evaluated in the same manner as in Example 1 except for using as an insulating layer a sputtered silicon oxide film (thickness: 30 nm) in place of the polyimide sheet. The results are shown in Table 1. The TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 5 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, under the same conditions as in Example 1), and oxygen permeability of 0.01 cc/m^2·day·atm or less (MOCON method, under the same conditions as in Example 1).

EXAMPLE 4

[0092] A support substrate was produced in the same manner as in Example 1, except for laminating the same polyimide sheet as in Example 1 on one surface of an aluminum foil and forming a silicon nitride layer (thickness: 50 nm) on the other surface of the aluminum foil by a sputtering method as insulating layers, instead of laminating polyimide sheets on both surfaces of the aluminum foil, and then forming a transparent cathode, an organic compound layer and an anode on the side of the silicon nitride insulating layer to produce a light-emitting device. The resultant light-emitting device was evaluated in the same manner as in Example 1. The results are shown in Table 1. The TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 3 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, under the same conditions as in Example 1), and oxygen permeability of 0.01 cc/m^2·day·atm or less (MOCON method, under the same conditions as in Example 1).

EXAMPLE 5

[0093] A light-emitting device was produced in the same manner as in Example 1, except for forming a silicon oxide layer (thickness: 40μm) only on one surface of the aluminum foil as an insulating layer by a sputtering method instead of laminating polyimide sheets both surfaces of the aluminum foil. A transparent cathode, an organic compound layer and an anode were formed on the side of the silicon oxide layer. The resultant light-emitting device was evaluated in the same manner as in Example 1. The results are shown in Table 1. The TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 10 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, under the same conditions as in Example 1), and oxygen permeability of 0.01 cc/m^2·day·atm or less (MOCON method, under the same conditions as in Example 1).

COMPARATIVE EXAMPLE 1

[0094] A light-emitting device was produced in the same manner as in Example 1 except for using a 50-μm-thick PET sheet available from Teijin Limited in place of a polyimide sheet as an insulating layer adhered to both surfaces of the aluminum foil. This light-emitting device was evaluated in the same manner as in Example 1. The results are shown in Table 1.

[0095] As is clear from Table 1, though this light-emitting device exhibited substantially the same initial properties as those of Examples, it was extremely poor in storing properties under humid and hot conditions, and many dark spots particularly due to the peeling of a cathode from the PET sheet were observed. The TMA measurement indicated that the support substrate had as large a linear thermal expansion

coefficient as 55 ppm/° C. The support substrate also had water permeability of 0.01 g/m^2·day or less (MOCON method, under the same conditions as in Example 1), and oxygen permeability of0.01 cc/m^2·day·atm or less (MOCON method, under the same conditions as in Example 1).

COMPARATIVE EXAMPLE 2

[0096] A light-emitting device was produced and evaluated in the same manner as in Example 1 except for using a support substrate constituted only by a 50-μm-thick polyimide sheet (UPILEX-50S, available from Ube Industries, Ltd.). The results are shown in Table 1. As is clear from Table 1, though this light-emitting device exhibited substantially the same initial properties as those of Examples, it was extremely poor in continuous driving properties and storing properties under humid and hot conditions, and many dark spots were observed. The TMA measurement indicated that the support substrate had a linear thermal expansion coefficient of 10 ppm/° C. The support substrate also had water permeability of 1.5 g/m^2·day (MOCON method, in the same manner as in Example 1), and oxygen permeability of 2.5 cc/m^2·day (MOCON method, in the same manner as in Example 1), both of them being large.

TABLE 1

No.	L_{max} (Cd/m²)	V_{max} (V)	η_{200} (%)	$t_{1/2}$ (hours)	$L_{max(30)}$ (Cd/m²)	$V_{max(30)}$ (V)
Example 1	68,000	12	15.1	3,800	52,000	14
Example 2	65,000	12	14.8	3,500	50,000	14
Example 3	67,000	12	14.0	3,500	49,000	14
Example 4	58,000	13	14.9	3,700	51,000	15
Example 5	56,000	12	14.5	3,500	48,000	14
Com. Ex. 1	48,000	15	12.5	1,100	3,400	34
Com. Ex. 2	9,000	20	8.1	110	850	35

[0097] As explained above in detail, because the light-emitting device of the present invention has a structure in which the emitted light is taken out from the opposite side to a substrate, using a flexible support substrate having as high gas barrier as that of glass and a linear thermal expansion coefficient of 20 ppm/° C. or less, it has excellent durability, light-emitting efficiency and luminance. Such light-emitting device is usable for plate-shaped light sources such as full-color display devices, backlights and illumination light sources, light source arrays of printers, etc.

What is claimed is:

1. A light-emitting device comprising an anode, at least one organic layer containing a light-emitting layer, and a cathode on a flexible support substrate, wherein said flexible support substrate has a linear thermal expansion coefficient of 20 ppm/° C. or less, said flexible support substrate has a water permeability of 0.01 g/m^2·day or less, and said flexible support substrate has a oxygen permeability of 0.01 cc/m^2·day·atm or less.

2. The light-emitting device of claim 1, wherein said flexible support substrate comprises a metal foil provided with an insulating layer on one or both surfaces thereof.

3. The light-emitting device of claim 2, wherein said flexible support substrate comprises a metal foil provided with an insulating layer on one surface thereof.

4. The light-emitting device of claim 2, wherein said flexible support substrate comprises a metal foil provided with an insulating layer on both surfaces thereof.

5. The light-emitting device of claim 1, wherein said flexible support substrate has a linear thermal expansion coefficient of 10 ppm/° C. or less.

6. The light-emitting device of claim 1, wherein said flexible support substrate has a linear thermal expansion coefficient of 8 ppm/° C. or less.

7. The light-emitting device of claim 2, wherein said metal foil is selected from the group consisting of an aluminum foil, a copper foil, a stainless steel foil, a gold foil and a silver foil.

8. The light-emitting device of claim 7, wherein said metal foil is an aluminum foil or a copper foil.

9. The light-emitting device of claim 2, wherein said insulating layer is made of a plastic selected from the group consisting of polyesters, polystyrenes, polycarbonates, polyether sulfones, polyarylates, allyldiglycolcarbonates, polyimides, polycyclolefins, norbornene resins and poly(chlorotrifluoroethylene).

10. The light-emitting device of claim 9, wherein said insulating layer is made of a polyimide.

11. The light-emitting device of claim 9, wherein said insulating layer constituted by a plastic sheet has a thickness of about 10 to about 200 μm.

12. The light-emitting device of claim 2, wherein said insulating layer is at least one of metal oxide and metal nitride.

13. The light-emitting device of claim 12, wherein said metal oxide is selected from the group consisting of silicon oxide, germanium oxide, zinc oxide, aluminum oxide and titanium oxide, and copper oxide, and wherein said metal nitride is selected from the group consisting of silicon nitride, germanium nitride and aluminum nitride.

14. The light-emitting device of claim 2, wherein the thickness of said metal foil is about 10 μm to about 100 μm.

15. The light-emitting device of claim 2, wherein the thickness of the inorganic insulating layer is about 10 nm to about 1000 nm.

16. The light-emitting device of claim 7, wherein said insulating layer is made of a plastic selected from the group consisting of polyesters, polystyrenes, polycarbonates, polyether sulfones, polyarylates, allyldiglycolcarbonates, polyimides, polycyclolefins, norbornene resins and poly(chlorotrifluoroethylene).

17. The light-emitting device of claim 7, wherein said insulating layer is at least one of metal oxide and metal nitride.

18. The light-emitting device of claim 17, wherein said metal oxide is selected from the group consisting of silicon oxide, germanium oxide, zinc oxide, aluminum oxide, titanium oxide and copper oxide, and wherein said metal nitride is selected from the group consisting of silicon nitride, germanium nitride and aluminum nitride.

19. The light-emitting device of claim 4, wherein said metal foil has an insulating layer made of plastics on one surface, and an insulating layer made of made of at least one of metal oxide and metal nitride on the other surface.

20. The light-emitting device of claim 19, wherein said metal foil has an insulating layer made of polyimide on one surface and an insulating layer made of at least one of metal oxide and metal nitride on the other surface.

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